The Canadian Entomologist

Vol. LXXXIX Ottawa, Canada, November 1957 No. 11

Bryobia arborea n. sp. and Morphological Characters Distinguishing It from *B. praetiosa* Koch (Acarina: Tetranychidae)[1]

By C. V. G. Morgan[2] and N. H. Anderson[3]
Entomology Laboratory, Summerland, B.C.

The clover, or brown, mite, *Bryobia praetiosa* Koch, was described in 1836 from specimens collected on shrubbery in Germany. The systematics of the species is complex and confusing. By 1838, Koch had described four species in the genus *Bryobia* but he preserved no type specimens and his descriptions do not agree with his illustrations (7, 12). Subsequent workers either placed Koch's species in synonomy or described new species. Two species, *speciosa* Koch and *ribis* Thomas, have created the most controversy. *B. speciosa* was accepted as valid by Koch, Berlese, Canestrini and Fanzago, and Oudemans, but rejected by von Hanstein and Trägårdh (2, 12). The gooseberry mite, *B. ribis*, was recognized as a valid species by Thomas and von Hanstein but Oudemans and Trägårdh placed it in synonomy with *B. praetiosa* (12). Further confusion was caused by the descriptions of additional new species of *Bryobia* and by descriptions of immature stages of *B. praetiosa* (8). The following taxonomic characters used by early acarologists in describing species of *Bryobia* have since been considered too variable for distinguishing species: number of femoral and tarsal hairs on the foreleg, body size, concavity of dorsum, and size and shape of cephalothoracic plate (7, 8, 12). Consequently, taxonomists have been at a loss to interpret Koch's original descriptions and subsequent redescriptions became inevitable. Because of the lack of morphological distinctions the modern trend has been to group all previously proposed species into one valid species (7, 8). As a result, 20 synonyms are now recognized for *B. praetiosa* (8).

In recent years acarologists have recognized several biotypes of *B. praetiosa*. At least four are known in Europe: one on fruit trees, one on gooseberry, one on ivy, and one on a range of herbaceous plants (6). Only two have been observed in North America: one on deciduous trees, especially orchard trees; and the other on herbaceous plants (13). However, none of the workers who found more than one biotype reported morphological distinctions to support their findings (5, 6, 8, 10, 11, 13-15). The desirability of morphological criteria to resolve the complex was recently stressed by Pritchard and Baker (8).

Studies conducted in the Okanagan Valley of British Columbia since 1952 have shown that the complex can be resolved on both morphological and ecological grounds. The morphological aspects presented in this paper prove that the mite on herbaceous plants is a distinct species from that on deciduous trees. The mite on fruit trees does not live on low-growing herbaceous plants such as grass and clover. McGregor's (7) description of *B. praetiosa* is applicable only to the mite on herbaceous plants. In fact, none of the 20 synonyms listed for this species by Pritchard and Baker (8) were described from specimens collected exclusively on fruit trees. However, the list does not include the synonym *B.* (= *Sannio*) *rubrioculus* (Scheuten), 1857, described from mites collected on pear at Bonn, Germany. In 1956, this name was resurrected from obscurity for most *Bryobia* mites found on apple and pear in western Europe (3). The validity of this action

1Contribution No. 3624, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
2Associate Entomologist.
3Assistant Entomologist; now at Entomology Laboratory, Belleville, Ont.

is questioned for two reasons: unfortunately, Scheuten's slide material has been lost; and we can never be certain what species Scheuten collected on the pear trees because recent ecological studies have shown that *B. praetiosa* may inhabit the same environment. With these facts in mind, we consider that the question can best be settled by proposing a new name, *B. arborea*, for the mite found exclusively on fruit trees.

Bryobia arborea sp. n.

Female.—In general appearance very similar to *praetiosa* as described by McGregor (7), but smaller in size. Body length 0.551 to 0.731 mm.; body width 0.348 to 0.527 mm.; foreleg (excluding coxa and tarsal claws) 0.543 to 0.659 mm. Lateral distances between the bases of the paired dorsocentral hysterosomal setae: DC_1, 0.047 to 0.084 mm.; DC_2, 0.027 to 0.061 mm.; DC_3, 0.020 to 0.044 mm.

Male.—Not found. Species parthenogenetic.

Larva.—Similar to *praetiosa* as described by McGregor (7) but body setae foliaceous like those of the adult (not lanceolate to clavate as in *praetiosa*). Body length 0.172 to 0.193 mm.; body width 0.143 to 0.164 mm. Lateral distances between the bases of the paired dorsocentral hysterosomal setae: DC_1, 0.035 to 0.053 mm.; DC_2, 0.017 to 0.030 mm.; DC_3, 0.013 to 0.022 mm.

Egg.—Spherical, slightly flattened at base. Diameter: 0.136 to 0.178 mm.

Holotype.—Collected on Delicious apple leaves, Summerland, B.C., June 13, 1955 (N. H. Anderson and H. Dominique). No. 6425 in the Canadian National Collection, Ottawa.

Paratypes.—Six females on slide containing holotype, same data; 12 females, collected on apple leaves, Vancouver, B.C., May 28, 1954 (J. H. McLeod); 12 females, collected on apple leaves, Vancouver, B.C., June 7, 1954 (J. H. McLeod); 13 females, collected on apple leaves, Vancouver, B.C., June 28, 1954 (J. H. McLeod); 23 females arranged on three slides, collected on apple leaves, Summerland, B.C., June 6, 1955 (H. Dominique and N. H. Anderson); 29 females arranged on three slides, collected on apple leaves, Summerland, B.C., June 13, 1955 (N. H. Anderson and H. Dominique); 32 females arranged on three slides, collected on apple leaves, Summerland, B.C., November 2, 1956 (C. V. G. Morgan).

B. praetiosa has been commonly known by two names, the clover mite and the brown mite. It is suggested that the former name be reserved for this species, and the the latter for *B. arborea*.

Morphological Characters Distinguishing *B. arborea* from *B. praetiosa*

Egg.—The eggs of *B. arborea* are usually smaller than those of *B. praetiosa* (Table I). The size of eggs of each species is consistent regardless of the locality in which they are collected. For example, *arborea* eggs collected in the comparatively wet coastal area of British Columbia fell within the same size range as those taken in the semi-arid Okanagan region.

Most workers (1, 4, 9) gave egg measurements considerably larger than those of mites found on herbaceous plants and apple trees in British Columbia. However, Wybou (14) reported measurements of eggs, apparently from apple in Belgium, similar to those of *praetiosa* eggs. It is possible that he measured *praetiosa* eggs, which are laid on tree trunks and sometimes far up on the scaffold limbs.

The eggs of both species are more or less spherical. Those of *praetiosa* may be somewhat irregular, particularly when they are laid in the soil on small stones and debris.

TABLE I
Morphological differences between *Bryobia arborea* n. sp. and *B. praetiosa* Koch
(measurements in microns)

Stage	Character	Number of specimens per species	*B. arborea*		*B. praetiosa*	
			Average	Standard deviation	Average	Standard deviation
Egg	Diameter	50	163	6	180	10
Larva (newly emerged)	Body length	20	186	6	201	9
	Body width	20	152	6	172	6
	Lateral distance between paired dorsocentral hysterosomal setae: DC_1	25	44	4	90	4
	DC_2	25	23	3	38	4
	DC_3	25	17	2	29	3
	Setal shape		foliaceous		lanceolate	
Adult	Setal shape		foliaceous		foliaceous	
	Body length	50	636	45	878	41
	Body width	50	440	45	630	47
	Foreleg length (excluding coxa and tarsal claws)	50	609	27	831	59
	Lateral distance between paired dorsocentral hysterosomal setae: DC_1	25	64	9	142	14
	DC_2	25	45	9	122	8
	DC_3	25	32	6	85	6

Larva.—Taxonomists have largely neglected the study of immature stages in their attempts to clarify the complex. The most distinctive morphological differences between the two species in British Columbia were found in the larval stage. Three distinguishing features are body size, shape of the dorsal setae, and position of the three pairs of dorsocentral hysterosomal setae. These characters are most easily observed immediately after eclosion and before extensive feeding. As with the eggs, the larvae of *B. arborea* are smaller than those of *B. praetiosa* both in body length and in body width (Table I).

Acarologists have emphasized the difference in shape between the larval and adult setae (9, 12). According to McGregor's (7) monographic work, the larval stage differs from the adult as follows: "The dorsal body setae are not leaflike, but are lanceolate to clavate, and conspicuously setose." This setal difference is found only in *B. praetiosa* (Fig. 1). Body setae of all specimens of *arborea* examined in British Columbia are similar in shape to those of the adult. The larval setae of *arborea* are foliaceous in shape. It is important that the setae be examined from a dorsal or ventral aspect, as in a lateral view the setae of the two species appear similar in shape.

B. arborea and *B. praetiosa* larvae also differ in the placement of the paired setae DC_1, DC_2, and DC_3 (Fig. 1 and Table I). In *praetiosa* the distance between the bases of the pair of DC_1 is approximately twice as great as in *arborea*. The distances between the setae are not proportional to the body width.

Adult.—Many workers have attempted to find morphological characters of specific rank in the adult. It is desirable to identify mites in this stage as ecological studies often commence with the adult. Specific morphological differences are less discernible in the adults than in the larvae because differences between adults of the complex are based largely on measurements. Early workers

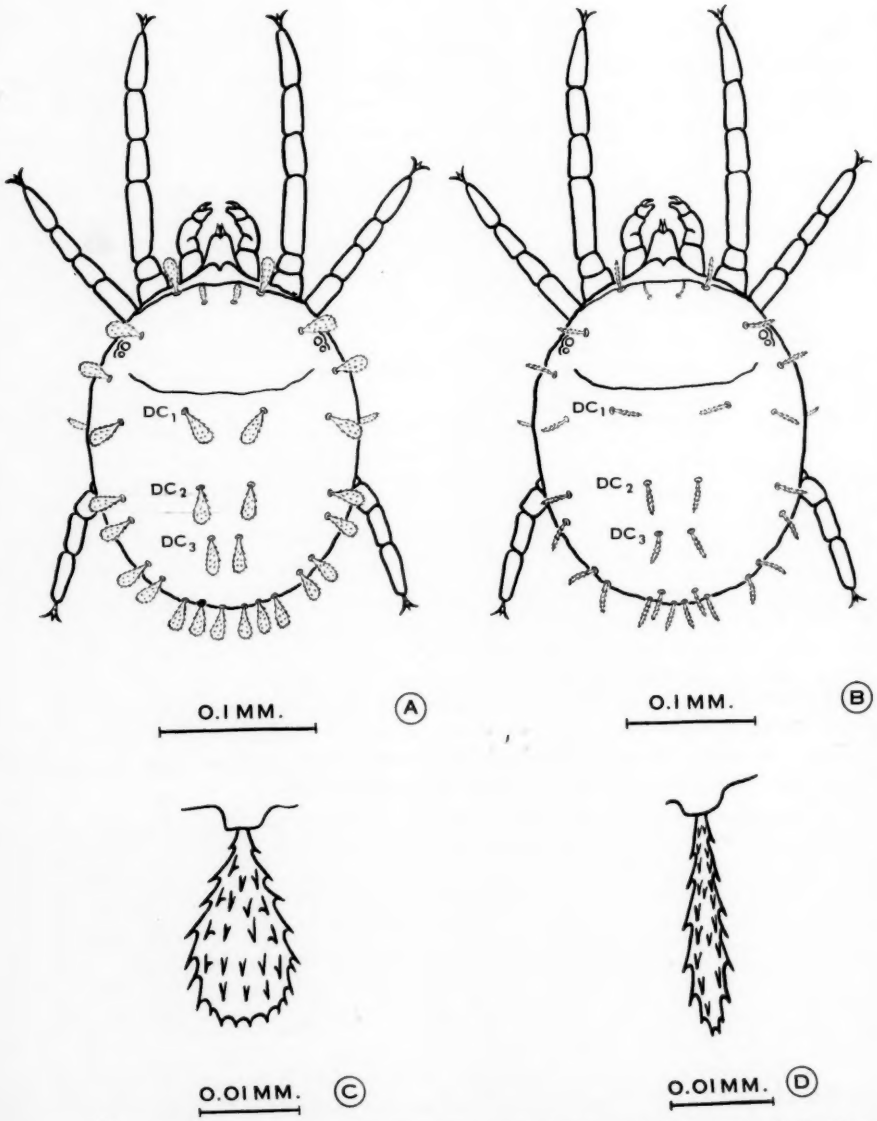


Fig. 1. Larvae of *Bryobia arborea* and *B. praetiosa*. Leg setae not illustrated. A, *B. arborea*; B, *B. praetiosa*; C, dorsal seta of *B. arborea*; D, dorsal seta of *B. praetiosa*.

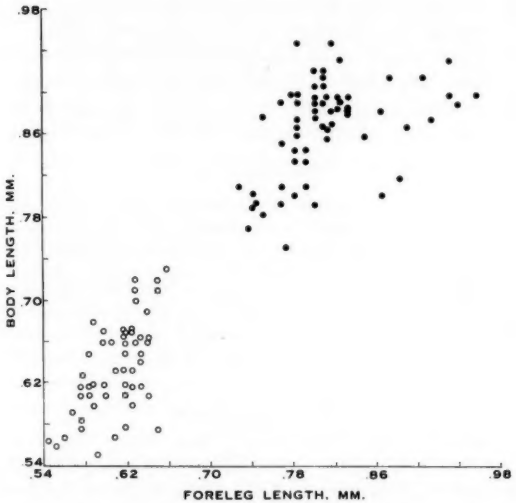


Fig. 2. Lengths of the foreleg (excluding coxa and tarsal claws) and body of adults of *B. arborea* (o) and *B. praetiosa* (●) collected in the Okanagan Valley and at Vancouver, B.C. Measurements taken from slide-mounted specimens.

attempted to differentiate *Bryobia* species by body size and length of foreleg. These characters were not accepted by later workers, who considered them too variable. Nevertheless, we have found that adults collected in British Columbia can be separated into two species by body size alone. The adults of *B. praetiosa* are definitely larger than those of *B. arborea* in length, width, and depth of body and in length of foreleg. For comparative purposes, foreleg and body length are the most reliable measurements as these structures suffer less distortion in slide preparation. As indicated in the scatter diagram (Fig. 2), measurements of the foreleg (excluding coxa and tarsal claws) and body length of *B. praetiosa* adults do not overlap those of *B. arborea.* These differences between the two species were consistent irrespective of geographical areas. It is possible that under adverse conditions of nutrition, etc., *praetiosa* adults may be smaller than those shown in the diagram and thus their measurements may overlap those of *arborea.* However, such adults were not encountered in this investigation. Adults do not acquire their normal body size until after their initial feeding period. *Praetiosa* adults on emergence from the last quiescent stage are similar to mature *arborea* adults in general appearance. Measurements should be taken, therefore, only on mature adults.

The shape and size of the adult setae are similar in both species but, as in the larvae, the setae DC_1, DC_2, and DC_3 differ in position (Table I). The bases of the paired setae of *praetiosa* are over twice as far apart as those of *arborea.* Although the *praetiosa* adult is larger than that of *arborea*, the considerably wider separation between the paired setae of the former cannot be accounted for by the difference in body size alone. Evidently the chaetotactic pattern is a distinctive feature.

For taxonomic purposes the most important distinguishing character listed in Table I is the shape of the larval setae. Individual adults can be distinguished

by measurement of one of the following: foreleg length, body length, and the lateral distance between the paired setae DC_1, DC_2, and DC_3.

A key to the known species of the genus *Bryobia* is given by Pritchard and Baker (8). To their key may be added the following couplet to separate *B. arborea* from *B. praetiosa*. Couplet 5 is taken directly from Pritchard and Baker with the substitution of the number "*6*" for "*praetiosa*" in the last line.

5(3). Empodium I consisting of a short pad with ventral rows of tenent hairs; males common ..... *cristata* (p. 22)

5(3). Empodium I consisting of a single pair of tenent hairs; males unknown 6

6(5). Foreleg of adult longer than 0.69 mm.; body length more than 0.74 mm.; lateral distance between bases of anterior pair of dorsocentral hysterosomal setae (DC_1) greater than 0.10 mm. Larval setae lanceolate, unlike those of adult; lateral distance between bases of DC_1 approximately four times length of seta ..... *praetiosa*

6(5). Foreleg of adult less than 0.69 mm. long; body length less than 0.74 mm.; lateral distance between bases of DC_1 less than 0.10 mm. Larval setae foliaceous, like those of adult; lateral distance between bases of DC_1 approximately twice length of seta ..... *arborea* sp. n.

Acknowledgments

We wish to acknowledge the field and laboratory assistance of Mr. Harry Dominique, Mr. George Yaminaka, and Miss Margaret Hall, formerly of the Entomology Laboratory, Vancouver, B.C. Assistance of the following in translating foreign language papers is greatly appreciated: Dr. J. Marshall and Mr. A. D. McMechan, Entomology Laboratory, Summerland, B.C.; Mr. A. A. Beaulieu, Science Service Laboratory, St. Jean, Quebec; and Dr. J. Sanjean and Dr. M. D. F. Udvardy, Department of Zoology, University of British Columbia, Vancouver.

References

(1) André, M. 1941. Sur le *Bryobia praetiosa* Koch (Acarien). *Bull. mus. natl. hist. nat., 2e ser.*, 13: 259-265.

(2) André, M. 1941. Sur le *Bryobia praetiosa* Koch (Acarien) (suite). *Bull. mus. natl. hist. nat., 2e ser.*, 13: 430-434.

(3) Eyndhoven, G. L. van. 1956. *Bryobia cristata* (Dugès 1834) and *Bryobia rubrioculus* (Scheuten 1857) (Acar.) (Notulae ad Tetranychidas 3). *Ent. Berichten* 16: 45-46.

(4) Garman, P. 1940. Tetranychidae of Connecticut. *Connecticut Agr. Expt. Sta. Bull.* 431.

(5) Geijskes, D. C. 1939. Beiträge zur Kenntnis der europäischen Spinnmilben (Acari, Tetranychidae) mit besonderer Berücksichtigung der niederländischen Arten. *Meded. Landbouwhogeschool Wageningen* 42: 1-68.

(6) Mathys, G. 1954. Contribution ethologique à la resolution du complexe *Bryobia praetiosa* Koch (Acar., Tetranych.). *Mitt. Schweiz. Ent. Ges.* 27: 137-146.

(7) McGregor, E. A. 1950. Mites of the family Tetranychidae. *American Mid. Nat.* 44: 257-420.

(8) Pritchard, A. E., and E. W. Baker. 1955. A revision of the spider mite family Tetranychidae. *Pacific Coast Ent. Soc. Mem. Ser.*, Vol. 2. *California Acad. Sci., San Francisco*, California.

(9) Riley, C. V., and C. L. Marlatt. 1890. The clover mite. (*Bryobia pratensis* Garman.). *Insect Life* 3: 45-52.

(10) Roesler, R. 1952. The gooseberry mite (*Bryobia praetiosa* Koch) in the Palatinate. *Höfchen-Briefe (English ed.)* 5: 15-18.

(11) Roosje, G. S., and J. B. M. van Dinther. 1953. The genus *Bryobia* and the species *Bryobia praetiosa* Koch. *Ent. Berichten* 14: 327-336.

(12) Trägårdh, I. 1914. Krusbarskvalstret *Bryobia praetiosa* K. *Medd. Centralanst. Forsoks. Jordbr.* 92 (*Ent. Avd.* 17): 1-24.

(13) Venables, E. P. 1943. Observations on the clover or brown mite, *Bryobia praetiosa* Koch. *Canadian Ent.* 75: 41-42.

(14) Wybou, A. 1951. De Acari der Fruitbomen. *Compt. rend. inst. encour. rech. sci., Bruxelles* 5: 85-126.

(15) Zacher, F. 1922. Biologie, wirtschaftliche Bedeutung und Bekampfung der Spinnmilben. *Verh. deut. Ges. angew Ent. 3, Mitgliederversammlung*, pp. 59-64.

Natural Occurrence of Glycerol in Insects and Its Relation to Their Ability to Survive Freezing[1]

By R. W. SALT[2]
Crop Insect Section, Science Service Laboratory
Lethbridge, Alberta

Introduction

When Wyatt and Kalf (in press) reported the presence of glycerol in the haemolymph of *Hyalophora cecropia* (L.) pupae, the possibility that it was responsible for the ability of this stage to survive freezing was naturally raised. It is well known that glycerol may protect animal tissues from injuries otherwise caused by ice formation. Many other substances have a degree of similar protective ability but are less effective for various reasons. Lovelock (1954) tested the protective action of 15 neutral solutes on human red blood cells and found glycerol to be almost ideal because of its high solubility in aqueous salt solutions, its ability to permeate the cell rapidly and completely, its low molecular weight, and its absence of toxicity even when in great excess.

The present study was undertaken to determine whether insects that can withstand freezing are distinguishable from those that cannot by a greater content of glycerol.

Materials and Methods

Freezing-resistant insects were represented by hibernating larvae of the goldenrod gall-fly, *Eurosta solidaginis* (Fitch), some of which the author knew to have survived, pupated, and emerged after an 18-day exposure to -55°C. Two pupae of *Antheraea polyphemus* (Cram.), reared in the laboratory and stored at 5°C., were available for experimentation; these may have been less cold-hardy than outdoor specimens, since a third pupa succumbed to freezing between -25° and -30°C.

A variety of insects were used to represent the freezing-susceptible group, which cannot survive freezing.

Glycerol was identified and in most cases approximated quantitatively by a chromatographic method, somewhat modified from a method kindly supplied by Wyatt. Chromatograms were run on Whatman No. 1 paper in three solvent systems: 80 per cent secondary butanol, butanol-acetic acid-water (4:1:5), and 95 per cent ethanol-ammonium hydroxide (95:5). The spray reagent was a modified form of that described by Lemieux and Bauer (1954), 0.5 per cent sodium metaperiodate being substituted for 2.0 per cent in order to hasten colour development. The best results were obtained with the butanol-acetic acid solvent, in which 10-15 micrograms of glycerol could be detected; ethanol-ammonia was not as sensitive, but otherwise satisfactory; after 80 per cent secondary butanol the spray treatment often caused browning of the paper during development, thus obscuring the spots.

Preliminary tests were made by cutting a specimen and applying the exudate to the chromatogram, or by macerating specimens in a few drops of 80 per cent ethanol and applying the more fluid portion. Most such tests produced streaking and indefinite results. Quantitative results were obtained from extracts prepared by homogenizing known weights of insect (0.5 to 5 grams) in 60 per cent ethanol, centrifuging, evaporating the supernatant portion to dryness in a vacuum, and taking up the residue in 1 ml. of water. These preparations were kept frozen when not in use. Known volumes of them were run alongside glycerol standards.

[1]Contribution No. 3643, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
[2]Research Officer.

TABLE I

Percentages of glycerol in three insect forms that differ in ability to withstand freezing, determined on chromatograms run in three solvents and calculated on a wet-weight basis. Each figure represents the approximate value or range of values for a single set of determinations.

	Secondary butanol	Butanol-acetic	Ethanol-ammonia
Loxostege sticticalis larvae	2.2 2.5	2.4 2.9 2.9–4.3	2.0–2.3 2.9–4.3
Eurosta solidaginis larvae	2.1	1.6–2.0 2.1 2.4–2.8	2.4
Antheraea polyphemus pupae	0.7 0.7	0.7–1.0 1.0	1.2–1.3

Results

All of the freezing-susceptible forms except one contained only doubtful traces of glycerol. These were: *Phormia regina* (Meig.) larvae, pupae, adults; *Anagasta kuehniella* (Zell.) larvae, pupae, adults; *Tenebrio molitor* L. larvae, pupae, adults; *Melanoplus bivittatus* (Say) eggs[3], nymphs; *M. mexicanus* (Sauss.) nymphs; *Cephus cinctus* Nort. larvae[3]; *Hylemya brassicae* (Bouché) pupae[3]; *Oryzaephilus surinamensis* (L.) adults; unidentified aphids from greenhouse alfalfa.

The exception was *Loxostege sticticalis* (L.), which contained 2 to 4.5 per cent glycerol. In two tests with this species the blood and the bloodless (washed) bodies were separated; the blood approximated 4.0 to 4.6 per cent glycerol and the bodies 1.5 to 2.0 per cent.

Table I gives the results of several tests with *Loxostege sticticalis* larvae, which cannot survive freezing; *Eurosta solidaginis* larvae, which can survive freezing; and *Antheraea polyphemus* pupae, which can withstand some freezing.

Discussion

The comparatively large amount of glycerol found in freezing-susceptible *L. sticticalis* larvae makes it apparent that the simple presence of glycerol in such amounts cannot be held responsible for protection against freezing. Nevertheless, the evidence that glycerol does protect a variety of animal cells and tissues is very convincing. All of the freezing susceptible insects tested, except *L. sticticalis*, offer indirect support by their lack of glycerol.

It is possible that glycerol is distributed in *L. sticticalis* in such a way as to have little or no protective value against freezing. The blood had two or three times as much glycerol as the remaining tissues, which themselves may exhibit differences. Little is known of the relative susceptibilities of different insect tissues to freezing, so that it is not yet possible to say what is vital and what is not. However, observations by the writer on mature larvae of the wheat stem sawfly, *Cephus cinctus* Nort., frozen (by inoculation with water on the cuticle) for one hour at constant temperatures between -6 and -20°C., showed that the heart continued beating for periods up to 32 days after -6°, 20 days after -15°, and 6 days after -20°C. Other muscular activity was detected for somewhat shorter periods. This suggests that both muscle tissue and its nerve supply may be uninjured by freezing, and that they die eventually from lack of supply from

[3]Hibernating stage.

supporting tissues, or from disruption of general metabolism. It was observed that muscular activity progressively deteriorated. On the other hand, the muscles or nerves may be slightly injured by freezing and yet function for some time. However, since slight injuries are apt to be repaired when the organism is otherwise intact, the indications are that the muscles and nerves are either uninjured by freezing, or, if injured, are affected merely as parts of a more extensive and generalized dysfunction.

The work of Lovelock (1954) on the freezing of human red blood cells gives a clue to another interpretation of the present results. He states, "Briefly, damage in freezing is a consequence of the increase in concentration of electrolytes within and without the cell. In the presence of glycerol the electrolyte concentration at temperatures below the freezing point is greatly diminished, by an amount sufficient to explain the protection afforded by glycerol. The effect of glycerol in lowering the concentration of electrolytes in equilibrium with ice at temperatures below 0° is a simple consequence of the colligative properties of solutions. It follows that the protective action of glycerol is unlikely to be unique, and that other neutral solutes of low molecular weight which are non-toxic and which can penetrate the cell should also protect it." Lovelock demonstrated this to be true of a variety of neutral solutes and red blood cells. As the protective effects are essentially additive, small amounts of many such solutes could produce an adequate total effect without any one being a major constituent. However, the concentration of glycerol, the most effective solute, needed to protect red blood cells was 19 per cent (w/v) at -30° and 24 per cent at -40°C. If neutral solutes are to protect insects similarly they must form an exceedingly high percentage of the non-aqueous fraction, which seems unlikely, or else be concentrated in vital tissues if such exist.

An interesting sidelight on the above is its bearing on the controversy between those studying the freezing of animal tissues and those studying the freezing of plant tissues. Meryman (1956), speaking of animal tissues, states, "The lethal factor, as a direct result of crystal formation, is the exceedingly high concentration of electrolyte resulting from the removal of water from solution." Lovelock is quoted as one of two authorities for this statement. Levitt (1957) points out in rebuttal to Meryman that plant physiologists have flatly rejected this theory for over 40 years. It is pertinent that Lovelock's theory of the protective action of neutral solutes assumes the veracity of the electrolyte-injury theory. In other words, since the concentrating of electrolytes during ice formation is reduced by the presence of neutral solutes, the injuries allegedly caused are proportionately reduced. The failure of glycerol to protect *L. sticticalis* larvae against freezing whereas similar amounts protected *E. solidaginis* larvae may suggest that the electrolyte-injury theory is inadequate. Otherwise it is necessary to assume that *E. solidaginis* possesses a rich supply of neutral solutes in addition to glycerol.

Acknowledgments

Thanks are due to Dr. G. R. Wyatt of the Biochemistry Department, Yale University for supplying the essentials of the methods and for criticizing the manuscript, and to Drs. R. Kasting and A. J. McGinnis of the Science Service Laboratory, Lethbridge, for their valuable interest and advice.

References

Lemieux, R. U., and H. F. Bauer. 1954. Spray reagent for the detection of carbohydrates. *Anal. Chem.* 26: 920-921.

Levitt, J. 1957. Mechanism of freezing in (plant or animal?) living cells and tissues. *Science* 125: 194.

Lovelock, J. E. 1954. The protective action of neutral solutes against haemolysis by freezing and thawing. *Biochem. J.* 56: 265-270.
Meryman, H. T. 1956. Mechanics of freezing in living cells and tissues. *Science* 124: 515-521.
Wyatt, G. R., and G. F. Kalf. (in press) Organic components of insect haemolymph. Proc. 10th Int. Congr. Ent. (Abs.).

(Received September 4, 1957)

Artificial Insemination of *Aedes aegypti* (L.)[1]

By ELDEN BURCHAM[2]
Department of Zoology and Entomology, Ohio State University
Columbus, Ohio

The technic of artificial insemination of insects offers a possible method for initiating or maintaining colonies of species which do not mate under laboratory conditions, and thus it may be possible to obtain a better understanding of their biology and permit the study of certain disease vectors. The technic might be applied to the study of the heredity of some species; it could be an aid to the taxonomist in the determination of species of questionable category.

The mechanical transfer of sperm by a pipette method has been employed for the honeybee (Watson, 1927), silkworm (Omura, 1936) and *Drosophila* (Gottschewski, 1937). The pipette technic has now been successfully employed for *Aedes aegypti*. Hayes' (1953) lack of success in artificial insemination of *Aedes aegypti* may have been due to a failure to introduce the sperm directly into the *bursa copulatrix*.

The mosquitoes used in the insemination procedure were reared by a standard laboratory method (Burcham, *et al.*, 1956). Males, 24 to 36 hours after their emergence, were separated from the females and fed 10 per cent sucrose solution for 9 to 14 days before being used. Unmated females were obtained by selecting their pupae. Females upon emerging were fed the sucrose solution for 7 to 12 days before insemination.

The pipette used for insemination was a pyrex capillary tube drawn to a diameter that would fit over a 23 gauge hypodermic needle, which had been cut off one-fourth inch from the hub. The capillary tube was cemented with sealing wax to the hub of the needle and the opposite end was drawn to an outside diameter of 45 to 75 microns. The needle hub was fitted in one end of a rubber tube which had at the other end a plastic mouthpiece.

The accessory glands and seminal vesicle were dissected from a male and transferred to a minute drop of physiologic saline. Several such preparations were made and kept covered to prevent desiccation while preparing the females.

Females to be inseminated were anesthetized with carbon dioxide for one minute. A female was then placed dorsum downward in a holding block and held in place with two *minuten nadeln*, each bent into a U shape. For convenience in manipulation it was necessary to have the abdomen directed upward at about 45°. The block was then placed under the microscope with the posterior of the female to the operator's left.

To prepare the insemination fluid, the accessory glands were crushed and a portion of the extruded granular material was aspirated into the pipette; without removing the pipette from the drop of saline, the seminal receptacle was ruptured and sperm was drawn into the pipette in the greatest possible concentration.

The pipette with the insemination medium was immediately transferred to the vulva. The vulva was exposed by grasping the cerci of the female with

[1]The investigation on which this paper is based was supported by research grant E-528(C7) from the National Institutes of Health, U.S. Public Health Service.
[2]Present address—Department of Zoology, University of Kentucky, Lexington, Kentucky.

jeweler's tweezers and gently pulling posteriorly until the ninth sternite was exposed; the sternite forms the dorsal lip of the vulva. This manipulation exposed the atrium. The filled pipette was then placed between the atrial plates of the ninth sternite which is exactly over the opening to the bursa copulatrix. The contents of the pipette was forced into the bursa copulatrix by the operator gently exerting air pressure. The bursa is collapsed in the unmated condition and as the fluid is forced into it a sudden slight expansion of the eighth abdominal segment is observed. The force being exerted was immediately stopped because force beyond this point usually ruptured the bursa.

For each replicate of the attempted insemination, the control females and those to be inseminated were divided into two groups, one group was fed mouse blood 48 hours before treatment and the other 24 hours after treatment. Mosquitoes of both groups were permitted only a single blood meal. Four controls were employed for each group, using accessory gland in saline, saline alone, carbon dioxide anesthesia for 30 minutes following a one minute initial exposure, and no treatment.

All mosquitoes were caged individually on squares of moist paper toweling. Eggs were removed daily and records of individual oviposition were kept over a 14 day period. The eggs were held on moist cotton for development for five days. After this period, 50 per cent of the eggs of the inseminated groups were dissected to check for fertility. If a fertile egg was found, dissection was not carried beyond the first fertile egg encountered. The groups in which fertile eggs were found were then checked for hatch and development to the adult stage. Fifty per cent of the eggs from the control groups were dissected every 5 to 6 days, and the remaining eggs were placed in water to check for hatch. At the end of 10 to 11 days the remaining unhatched and undissected eggs of all groups were dissected.

Four replicates of inseminations have been completed, using a different saline for each. A total of 175 females were inseminated and 84 survived to oviposit. Fifteen of the ovipositing females laid some fertile eggs; a total of 1129 eggs were laid, and 181 or 16 per cent of these were fertile. In several instances a female laid only one fertile egg. The highest per cent of fertile eggs oviposited by any one female was 70 per cent. The descendants of several inseminated females were reared through two generations with apparently normal mating and oviposition. None of the control groups produced fertile eggs.

This method does not achieve insemination at the natural level; however, with improvements in technic and saline diluent for the sperm, it should be possible to obtain a higher rate of successful inseminations. A preliminary test of terramycin at 0.1 mg. per 100 ml. of saline has substantially reduced the mortality rate of females and increased the rate of successful inseminations. It is anticipated that this technic may be used successfully to inseminate artificially other species of mosquitoes.

References

Burcham, Elden G., Arden O. Lea, John B. Dimond, and D. M. Delong. 1956. "Laboratory Rearing Procedures for *Aedes aegypti* and *Culex pipiens*." 7 pp. North Cen. Br. Papers, Wis. Alumni Res. Found., Insecticide Testing Lab., Madison, Wis.

Gottschewski, G. 1937. Künstliche Befruchtung bei *Drosophila*. *Naturwissensch.*, 25: 650.

Hayes, Richard O. 1953. Studies on the artificial insemination of the mosquito *Aedes aegypti* (L.). *Mosquito News*, 13: 145-152.

Omura, Seinosuke. 1936. Artificial insemination of *Bombyx mori*. *Jour. Faculty of Agr. Hokkaido Imp. Uni.*, 38: 135-150.

Watson, L. R. 1927. Controlled mating of the honeybee. Part 2—How it is accomplished. *Am. Bee Jour.*, 67: 300-302.

Observations sur les Dégâts Causés par le Charançon de la Prune, *Conotrachelus nenuphar* (Hbst.), sur les Pommes dans le Sud-Ouest du Québec[1]

Par R. O. Paradis[2]

Section des Insectes des Cultures, Laboratoire du Service des Sciences
Saint-Jean, Québec

English Summary

Field studies in southwestern Quebec showed that *feeding scars* of the plum curculio *Conotrachelus nenuphar* (Hbst.), were made by overwintered and summer adults and occurred throughout the growing season. *Egg-laying scars* were made by overwintered adults only and occurred from the time of apple set to early August. The latter category included *deep entries*, which were made by the developing larvae in the fruit. In the McIntosh and Lawfam varieties feeding scars were found in 37.4 and 35.0 per cent respectively, averaging 36 per cent for the combined varieties, and egg-laying scars in 62.6 and 65.0 per cent, averaging 63.8 The extent of the two types of damage in the field appeared to be the reverse of those observed in the insectary, where feeding scars for the combined varieties averaged 63.2 per cent and egg-laying scars 36.8 per cent. In the insectary, 41.1 and 22.1 per cent of the feeding scars were respectively contributed by overwintered and summer adults. It was not possible to estimate these fractions in the field.

On heavily infested Lawfam apple trees near woodland areas and lightly infested ones in the same orchard 70.3 and 56.8 per cent respectively of the apples dropped prematurely, the difference being statistically significant. Of the fallen apples 26.8 per cent of the former and 3.9 per cent of the latter showed egg-laying scars. A similar comparison of heavily and lightly infested McIntosh apple trees did not show significance between apples dropped prematurely and those showing egg-laying scars. This variety was markedly more resistant to plum curculio egg and larval development than the Lawlam variety. Since eggs were laid on apple of both varieties in approximately equal numbers, resistance appears to be the result of tissue growth killing the eggs and hardness of tissue preventing the successful establishment in the fruit of newly emerged larvae.

Introduction

Des recherches ont été poursuivies, en ces dernières années, sur le Charançon de la prune en tant que parasite de la pomme dans le sud-ouest du Québec. Un des aspects de ces recherches avait trait aux déprédations causées par cet insecte.

Les différents genres de dégâts du Charançon de la prune sur les pommes sont assez bien connus pour avoir été décrits à plusieurs reprises tant par des entomologistes des Etats-Unis (Crandall, 1905; Quaintance et Jenne, 1912; Garman et Zappe, 1929; Chapman, 1938, etc.) que du Canada (Lockhead, 1919; Petch, 1927, etc.). Il est reconnu, par exemple, que pour se nourrir les adultes percent l'épicarpe de la pomme et creusent, dans la pulpe, des cavités d'une profondeur égale à la longueur de leur rostre, soit de 2 à 3 mm. Il est connu également que la femelle, au moment de la ponte, pratique une incision semi-circulaire à travers la pelure, pour chacun des oeufs insérés dans le fruit et que les larves se nourrissent à l'intérieur du fruit. Il restait cependant à déterminer, sous nos conditions de climat et de culture, les périodes durant

[1]Publication No. 3623, Division de l'Entomologie, Service des Sciences, Ministère de l'Agriculture du Canada, Ottawa.
[2]Entomologiste adjoint.

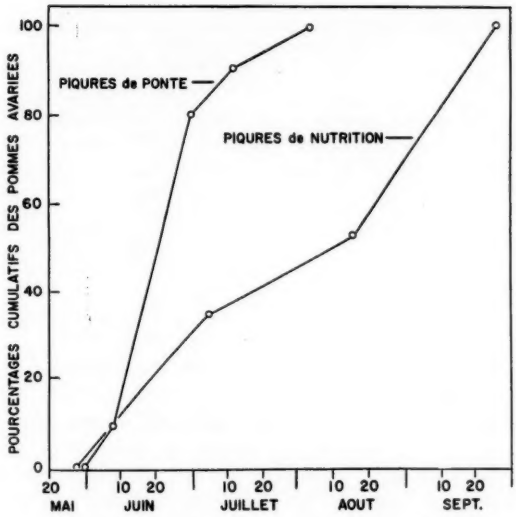


Fig. 1. Pourcentages cumulatifs des piqûres de ponte et de nutrition du Charançon de la prune sur les pommes. Rougemont, Qué., 1955.

lesquelles ces dégâts sont causés et aussi, l'importance de ces attaques en tant que facteur responsable de la tombée prématurée des fruits.

Méthodes de Travail

Ces études ont été poursuivies au cours de l'été 1955, à la sous-station de Rougemont, province de Québec.—En juin, juillet et août 1955, la température moyenne a été de cinq à six degrés Fahrenheit plus élevée que la normale; d'autre part la récolte de pommes a été particulièrement abondante.

Le verger expérimental consistait en une plantation uniforme de 500 pommiers comprenant les variétés McIntosh et Lawfam réparties en nombre à peu près égal.—Il s'agit de deux variétés dites de pommes d'hiver dont la cueillette se fait habituellement vers le 20 septembre.—Sur deux cotés, le verger était contingu à une érablière, endroit propice à l'hibernation du Charançon de la prune et de nature à favoriser sa pullulation. En fait, les rangées d'arbres adjacentes à la forêt étaient beaucoup plus infestées que le reste du verger. Ces différences de population sur des arbres relativement rapprochés a permis d'évaluer et de comparer la tombée des fruits chez des arbres fortement et légèrement infestés. Aucun insecticide n'a été appliqué sur ce verger au cours de la saison.

Aux données obtenues dans le verger se sont ajoutées les observations faites en insectarium où était maintenu l'élevage de ce Charançon.

Piqûres de Nutrition

Les piqûres résultant de la nutrition des adultes ont été pratiquées sur les pommes à partir du 27 mai, soit très peu de temps après la nouure des pommes, jusqu'au 23 septembre, date de la cueillette. La courbe, à la Fig. 1, illustre la distribution de ce genre de dégâts, au cours de la saison. Ainsi à la fin de mai et en juin, les adultes qui sortent d'hibernation se montrent très avides de nourriture, tandis que du début de juillet à la mi-août, le nombre des piqûres

TABLEAU I

Piqûres causées par le Charançon de la prune se nourrissant sur des pommes en insectarium. Rougemont, Que., 1955.

Sexe	Génération hibernante (27 mai–23 septembre)				Nouvelle génération (27 juillet–23 septembre)			
	Nombre d'individus	Nombre de piqûres			Nombre d'individus	Nombre de piqûres		
		Max.	Min.	Moy.		Max.	Min.	Moy.
Mâles	20	118	55	85.5	7	112	24	51.0
Femelles	16	143	56	112.8	9	76	33	53.7
Total	36	143	55	97.7	16	112	24	52.5

diminue sensiblement pour s'accroître à nouveau, durant tout le reste de la saison, avec l'apparition en nombre des adultes de la nouvelle génération.

Les piqûres de nutrition, pratiquées sur les jeunes pommes, se cicatrisent ordinairement, mais elles font que les fruits sont difformes et bosselés lors de la cueillette. Sur les pommes assez avancées dans leur développement, ces mêmes dégâts se manifestent par des trous ronds à travers la pelure et des cavités dans la pulpe, rendant ainsi les fruits impropres à la conservation.

Le nombre de piqûres de nutrition, tel que déterminé en insectarium, a été de 97.7 en moyenne par individu de la génération hibernante et de 52.5 par individu de la nouvelle génération. Au Tableau I, apparaissent, en plus, les nombres maximum, minimum et moyen de piqûres observées pour chacun des sexes et pour chacune des deux générations d'adultes.

Au cours de l'élevage, il a été donné d'observer que le Charançon de la prune, en plus de se nourrir sur les pommes, s'attaque parfois aux pétales des fleurs, aux bourgeons, aux jeunes pousses et aux feuilles.

Piqûres de Ponte

Dans le verger, les incisions semi-circulaires ou piqûres occasionnées par les femelles à la suite de la ponte sur les pommes ont été faites du 30 mai au trois août. Cependant c'est en juin (Fig. 1) que ces dégâts ont été numériquement les plus abondants.

En insectarium, le nombre de piqûres de ponte pour chacune des 23 femelles sous observation, a varié de 1 à 293 et a été en moyenne de 87.3 par femelle. Ce nombre est d'environ 5.6 pour cent plus élevé que le nombre d'oeufs déposés, car il a été noté que la femelle pratique parfois cette incision caractéristique au travers de la pelure sans y déposer d'oeuf.

Les proportions des piqûres de ponte et de nutrition, telles qu'observées dans le verger, sur les variétés McIntosh et Lawfam, sont présentées au Tableau II. Si l'on considère le nombre total de pommes avariées au cours de la saison, il y a prédominance marquée des piqûres de ponte sur celles de nutrition, leur proportion étant d'environ 64 et 36 pour cent quelle que soit la variété. Cependant, sur les pommes examinées au moment de la cueillette, les piqûres de nutrition sont numériquement plus abondantes, indiquant qu'un fort pourcentage de pommes marquées de piqûres de ponte sont tombées prématurément et sont en putréfaction lors de la récolte.

Les pommes portant des piqûres de ponte et parvenues à maturité sont bosselées et déformées à la façon de celles ayant des piqûres de nutrition, mais

TABLEAU II
Proportion des piqûres de ponte et des piqûres de nutrition causées par le Charançon de la prune sur les pommes dans le verger.
Rougemont, Qué., 1955.

Variété	Total des pommes avariées de la nouure à la ceuillette inclusivement			Total des pommes avariées à la ceuillette		
	Pommes avariées	Ponte %	Nutrition %	Pommes avariées	Ponte %	Nutrition %
Lawfam	4,729	65.0	35.0	874	22.9	77.1
McIntosh	1,454	62.6	37.4	436	40.8	59.2

elles conservent des cicatrices en forme de croissant. Les piqûres de ponte observées sur les pommes presque complètement développées sur l'arbre n'ont jamais révélé la présence de larve de charançon à l'intérieur du fruit.

Piqûres de Ponte et Chute des Pommes

La plupart des auteurs (Crandall, 1905; Quaintance et Jenne, 1912; Garman et Zappe, 1929; Whitcomb, 1932, etc.) s'accordent à dire que la larve du Charançon de la prune, en se nourrissant à l'intérieur de la pomme, amène invariablement la chute prématurée de celle-ci, sans quoi la larve ne peut atteindre le terme de son développement. Chapman (1938) et Detjen (1938) reconnaissent aussi ce fait, mais signalent que le Charançon n'augmente la tombée prématurée des fruits que lorsque sa population est réellement élevée ou encore que sur certaines variétés de pommes.—La chute prématurée des pommes attribuable au Charançon de la prune demeure difficile à évaluer vu qu'à la même période de la saison il se produit une tombée abondante de pommes (30 à 60 pour cent) à la suite de différentes causes d'ordre physiologique.

Les observations, faites au cours des présentes recherches, concordent d'abord avec le premier point établi, à savoir que la larve en se développant à l'intérieur de la pomme occasionne la chute de celle-ci. Quant au second point, relatif à l'augmentation de la chute normale des fruits, nos études ont porté précisément sur la chute des pommes des deux variétés concernées en relation avec les piqûres de ponte. Les proportions des fruits tombés chez des arbres fortement infestés et chez des arbres à peu près exempts de ce Charançon ont été établies et comparées.

Les résultats obtenus avec la variété Lawfam apparaissent au Tableau III. Chez les pommiers fortement infestés, la chute prématurée (survenue avant le 12 juillet) a atteint 70.3 pour cent du total des pommes; de ces pommes tombées, 26.8 pour cent étaient marquées de piqûres de ponte. Chez les pommiers légèrement infestés, la proportion des pommes tombées a été de 56.8 pour cent dont 3.9 pour cent avaient des marques de ponte. Ainsi, entre les deux catégories d'arbres, il y a eu une différence de 13.5 quant au pourcentage des pommes tombées et, d'autre part, une différence de 22.9 quant au pourcentage des pommes tombées ayant des piqûres de ponte. A l'analyse statistique ces différences se sont révélées significatives, impliquant qu'il y avait relation entre l'augmentation de la chute des pommes et le nombre de fruits attaqués par les femelles du Charançon.

Considérant la chute totale (s'étendant de la nouure des fruits à leur cueillette) chez cette même variété, il y a eu aussi relation entre l'augmentation

TABLEAU III

Chute prématurée et totale des pommes de la variété Lawfam en relation avec les piqûres de ponte du Charançon de la prune.
Rougemont, Qué., 1955.

	Chute prématurée (avant le 12 juillet)*		Chute totale (avant le 23 septembre)*	
	% moyen par arbre des pommes tombées	% moyen par arbre des pommes tombées avariées	% moyen par arbre des pommes tombées	% moyen par arbre des pommes tombées avariées
Arbres fortement infestés	70.3	26.8	76.4	26.6
Arbres légèrement infestés	56.8[1]	3.9	66.2[2]	3.6

* Moyenne de trois arbres.
[1]Différence significative minima (L.S.D.) à 1% = 8.72.
[2]Différence significative minima (L.S.D.) à 1% = 9.76.

des pommes tombées et la proportion des fruits avariés par la ponte, puisque les différences de part et d'autre ont été trouvées significatives.

La même comparaison a été faite avec les pommes de la variété McIntosh. Chez les arbres fortement infestés, la chute prématurée a été 51.7 pour cent du total des pommes; des pommes tombées, 16.7 pour cent avaient des piqûres de ponte. Chez les arbres légèrement infestés, la proportion des fruits tombés a été de 56.1 pour cent, dont 2.4 pour cent étaient avariées. Entre les deux catégories d'arbres, il n'y a pas eu de différence significative quant à la chute prématurée des pommes, mais il y a eu une différence significative quant à la proportion des fruits tombés et avariés à la suite de la ponte (Tableau IV). Les comptages concernant la chute totale des pommes (s'étendant de la nouure à la cueillette) ont donné des résultats semblables à ceux de la chute prématurée.

Discussion

Les résultats différents obtenus avec les deux variétés de pommes à l'étude, concernant les attaques du Charançon de la prune et la chute des fruits, nécessitent certains commentaires. *Variété Lawfam.*—Chez la variété Lawfam, malgré la relation existant entre la chute des fruits et les piqûres dues au Charançon, il y a eu un écart appréciable entre l'augmentation de la chute normale (13.5) et l'augmentation de fruits attaqués (22.9). Cette différence s'explique comme suit: 1) le nombre de larves parvenues à maturité et, par conséquent, responsable de la chute des fruits, a été nécessairement inférieur au nombre de piqûres de ponte; 2) un certain pourcentage de pommes, tombées à la suite des attaques de la larve, seraient tombées indépendamment de ces attaques, vu la chute prématurée annuelle d'une certain nombre de fruits.
Variété McIntosh.—Chez la variété McIntosh, les attaques du Charançon n'ont pas augmenté la chute des fruits. Ce fait trouve explication dans les données présentées au Tableau II. D'après ces données, le pourcentage des piqûres de ponte est sensiblement le même (65.0% et 62.6%) chez la variété McIntosh et Lawfam quant au total de pommes attaquées au cours de la saison; mais ce pourcentage est nettement différent sur les pommes examinées au moment de la cueillette. Chez la Lawfam, à la récolte, 22.9 pour cent des pommes avariées ont des marques de ponte, tandis que chez la McIntosh, la proportion est de 40.8 pour cent. Cette différence indique ou bien que l'éclosion des oeufs à l'intérieur de la variété McIntosh a été relativement faible, ou bien que les

TABLEAU IV

Chute prématurée et totale des pommes de la variété McIntosh en relation avec les piqûres de ponte du Charançon de la prune.
Rougemont, Qué., 1955.

	Chute prématurée (avant le 12 juillet)*		Chute totale (avant le 23 septembre)*	
	% moyen par arbre des pommes tombées	% moyen par arbre des pommes tombées avariées	% moyen par arbre des pommes tombées	% moyen par arbre des pommes tombées avariées
Arbres fortement infestés	51.7	16.7	62.7	15.3
Arbres légèrement infestés	56.1[1]	2.4	66.5[2]	2.5

* Moyenne de trois arbres.
[1]Différence non significative à 5%.
[2]Différence non significative à 5%.

larves sont mortes peu de temps après leur émergence, soit à la suite de la pression exercée par le développement du fruit, soit pour diverses autrés causes. De toute façon, il est plausible d'affirmer que chez la variété McIntosh il y a eu une réduction d'environ 17 pour cent, comparativement à la variété Lawfam, quant au nombre de larves qui ont atteint leur maturité.

Résumé et Conclusion

Les recherches, poursuivies en 1955, sur le Charançon de la prune, parasite de la pomme dans le sud-ouest du Québec, ont porté principalement sur l'importance respective des différents genres de déprédations causées par cet insecte.

Les adultes, qui sortent d'hibernation, se nourrissent sur les pommes dès que celles-ci sont nouées et continuent leur ravage jusqu'en septembre. Les adultes de la nouvelle génération, apparaissant en nombre au cours du mois d'août, se nourrissent également sur les pommes jusqu'au moment de la cueillette. Ces piqûres dites de nutrition, faites sur les jeunes pommes font que celles-ci sont difformes et bosselées à la récolte, tandis que, sur les pommes presque complètement développées ces piqûres résultent en des trous à travers la pelure et en des cavités dans la pulpe, rendant ainsi le fruit impropre à la conservation. En insectarium, le nombre moyen de piqûres de nutrition, par individu, a été 97.7 pour la génération hibernante et 52.5 pour la nouvelle génération.

C'est surtout en juin que les piqûres dites de ponte sont pratiquées par les femelles sur les pommes. Le nombre de piqûres a été 87.3 en moyenne par femelle. Les larves, qui émergent de ces oeufs, creusent des galeries à l'intérieur du fruit et occasionnent invariablement la chute de celui-ci. Cependant, les pommes dans lesquelles les oeufs n'éclosent pas et les larves ne peuvent se développer, atteignent leur maturité sur les arbres, mais elles sont déclassées à la récolte par suite des dépressions et des cicatrices qu'elles portent.

L'importance réelle des attaques de ce Charançon en tant que facteur responsable de la chute des pommes peut être assez difficile à déterminer, vu que, chaque année, indépendamment de cet insecte, il se produit une chute prématurée des fruits. Toutefois en comparant la tombée prématurée chez des arbres fortement et légèrement infestés, il a été trouvé, avec la variété Lawfam, qu'il existait une différence de 13.5 quant aux pourcentages de pommes

tombées et, d'autre part, une différence de 22.9 quant aux pourcentages des pommes tombées ayant des piqûres de ponte. Par contre, avec la variété McIntosh, il n'y a pas eu de relation entre le nombre de pommes tombées et le nombre de pommes ayant des marques de ponte, de sorte que le Charançon n'a pas augmenté la chute des pommes. Par ailleurs, cette variété s'est révélée très peu favorable au développement normal des larves.

Remerciements

L'auteur tient à remercier monsieur Philippe Martin, aide-saisonnier, qui a aidé à recueillir les différentes données au cours de cette étude.

Bibliographie

Chapman, P. J. 1938. The plum curculio as an apple pest. New York Agr. Expt. Sta. Bull. No. 684.

Crandall, C. S. 1905. The curculio and the apple. Illinois Agr. Expt. Sta. Bull. No. 98: 467-514.

Detjen, L. R. 1938. Physiological dropping of fruits.—III. Plum curculio injury to young fruits in relation to physiological drop. Delaware Agr. Expt. Sta. Bull. No. 212.

Garman, P. et M. P. Zappe. 1929. Control studies on the plum curculio in Connecticut apple orchards. Connecticut Agr. Expt. Sta. Bull. No. 301.

Lockhead, W. 1919. Class book of economic entomology. P. Blakiston's Son & Co.: 329-330.

Petch, C. E. 1927. The plum curculio (*Conotrachelus nenuphar* Herbst.) and its control in Quebec. Canada Dept. of Agriculture. Ent. Branch. Circ. No. 27 (rev.)

Quaintance, A. L. et E. L. Jenne. 1912. The plum curculio. U.S.D.A. Bur. Ent. Bull. No. 103.

Whitcomb, W. D. 1932. The relation of temperature and control of the plum curculio in apples. Massachusetts Agr. Expt. Sta. Bull. No. 285.

Notes on Life-histories of Four Species of Climbing Cutworms Collected from Low-bush Blueberry Fields in New Brunswick (Lepidoptera: Phalaenidae)[1]

By G. W. Wood and W. T. A. Neilson[2]

Fruit Insect Section, Entomology Laboratory
Fredericton, New Brunswick

As part of a comprehensive investigation on insects affecting the low-bush blueberry carried on in New Brunswick during the past eight years, the writers accumulated considerable information on several species of climbing cutworms that previously received little attention. Life-history notes on four species are presented in this paper: *Graphiphora smithi* (Snell.), *Graphiphora collaris* (G. & R.), *Eucirrhoedia pampina* (Gn.), and *Heptagrotis phyllophora* (Grt.). Each species by itself is not considered as a serious pest of blueberry, but these and other species may cause an appreciable reduction in the blueberry crop.

The notes are based on insectary-reared material, supplemented where possible by field observations. Larvae were collected by sweeping blueberry fields at night, and were reared in glass jelly jars or waxed cardboard cups with fresh blueberry foliage as food. Observations on oviposition were made possible by mating reared moths and from gravid females collected by light-trap. Records on parasitism are based on the study of cutworm larvae collected in the field and therefore do not include any species which parasitize the pupal stage.

Graphiphora smithi (Snell.)

Egg and Larva

The egg is spherical in shape, has dorsoventral striations, is creamy white when deposited, but turns greyish before hatching. It has a diameter of 0.8 mm.

[1]Contribution No. 3541, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.

[2]Associate Entomologist and Assistant Entomologist.

and a height of 0.6 mm. The eggs are laid in masses in well-arranged rows. In confinement they were laid on the sides and covers of the containers rather than on the blueberry foliage in the containers.

Newly hatched larvae are yellowish-green but become brownish before the first moult. The head capsule is light brown. The second instar is distinguished by two wide reddish-brown lateral stripes. The ventral surface is light grey to pale yellow. In the third instar a brown line extends onto the head capsule on both sides of the epicranial suture from the dorsal surface of the first thoracic segment. The dorsal surface of the body is light brown and the ventral surface is pale yellowish-green. Dorsally each segment has two reddish-brown stripes that begin at each of the subdorsal white lines, run diagonally caudad, cross at or near the transverse conjunctiva, and terminate on similar stripes in the next segment. This produces a diamond-shaped pattern on the dorsum that persists through succeeding instars. In the ultimate instar the body length is approximately 28 mm. and the width 4.5 mm.

Life-history

The larvae pass through seven instars. Head capsule measurements for each instar were as follows:—

Instar	I	II	III	IV	V	VI	VII
No. measured	38	52	75	81	72	24	18
Range, mm.	0.36–0.38	0.46–0.51	0.54–0.70	0.77–1.02	1.02–1.43	1.48–1.95	2.34–3.33
Mean, mm.	0.37	0.49	0.65	0.89	1.19	1.68	2.54

G. smithi overwinters in the soil as a partially grown larvae, usually in the third or fourth instar. Activity is resumed by the middle of the following April and feeding continues until late June or early July. Pupation takes place in the soil and adults emerge from late July to early September. Durations of pupation, pupal, and emergence periods are shown in Table I. The flight period ends by the middle of September.

Mating and oviposition take place shortly after emergence. The maximum number of eggs per female moth was 411. The incubation period of the egg is approximately 12 days under natural conditions, but at a constant temperature of 70°F. it was shortened to five days.

Parasitism

Parasitism of insectary-reared material was less than 25 per cent during the period of study but several species of parasites were obtained: *Zele crassicalcarata* Vier., *Meteorus communis* (Cress.), *Microplitis varicolor* Vier., *Rogas terminalis* (Cress.), and *Rogas* sp. [Hymenoptera: Braconidae]; *Nepiera marginata* (Prov.), *Hyposoter annulipes* (Cress.) [Hymenoptera: Ichneumonidae]; *Copidosoma bakeri* (Howard) [Hymenoptera: Encyrtidae]; *Wagneria helymus* (Wlk.), *Bonellimyia tessellata* Brks. [Diptera: Tachinidae].

***Graphiphora collaris* (G. & R.)**

Egg and Larva

The egg is circular in outline and roughly semi-circular in profile, with dorsoventral striations. It has a diameter of 0.8 mm. and a height of 0.6 mm. When laid the egg is pale yellow, but two days later a reddish-brown girdle and micropylar splotch appear and before hatching the entire egg turns reddish. In confinement, eggs were laid singly on blueberry foliage or among the debris at the bottom of the rearing container.

Newly hatched larvae are dark grey in colour with prominent setae and black setal tubercles. They become light brown before the first moult. Due to a scarcity of specimens no descriptions of the second and third instar were made. In the remaining instars the general body colour varies from light to dark brown. There are a white mid-dorsal line and two white subdorsal lines. Between them the surface is dark brown near the mid-dorsal line and light brown near the subdorsal line. A broad, white spiracular stripe is prominent on each side. The ventral surface is light brown. In the ultimate instar the body length is approximately 27 mm. and the width 4.5 mm.

Life-history

The larvae pass through seven instars. No measurements of second-instar larvae were made from rearings or field collections and the mean length given below was obtained by multiplying the mean length of the first instar by the average growth ratio for succeeding instars as described by Lejeune (1950). Head capsule measurements for each instar were as follows:—

Instar	I	II	III	IV	V	VI	VII
No. measured	10	—	1	10	14	23	15
Range, mm.	0.38–0.42	—	0.70–	0.79–1.06	1.09–1.43	1.51–1.77	2.08–2.47
Mean, mm.	0.40	0.53	0.70	0.97	1.25	1.66	2.30

G. collaris overwinters in the soil as a partially grown larvae, apparently in the third or fourth instar. Larvae become active again in early April and feed until late June or early July. Pupation takes place in the soil and adults emerge during late August and early September. Mating and oviposition take place shortly after emergence and the eggs hatch during September, after an incubation period of approximately 18 days.

Parasitism

Parasites reared from this host were: *Apanteles* sp., *Rogas terminalis* (Cress.), and *Rogas* sp. [Hymenoptera: braconidae]; *Campoletis* sp. and *Ophion* sp. [Hymenoptera: Ichneumonidae]; *Dibrachys cavus* (Wlk.) [Hymenoptera: Pteromalidae].

Eucirrhoedia pampina (Gn.)

Egg and Larva

The egg is circular in outline and approximately semi-circular in profile, with dorsoventral striations. When laid it is pale yellow but turns reddish-brown within two or three days. It has a diameter of 0.8 mm. and a height of 0.6 mm. In confinement eggs were laid singly on blueberry foliage and on the bottom of the container.

In all instars the colour pattern of the larva remains very simple. The general body colour is a dull red with a white mid-dorsal line. There are a white subdorsal line and a white spiracular stripe on each side, but these lines nearly disappear in the later instars. White setal tubercles remain prominent in all instars. Larvae attain a length of approximately 24 mm. and a width of 5 mm.

Life-history

The larvae pass through six instars. Head capsule measurements for each instar were as follows:—

Instar	I	II	III	IV	V	VI
No. measured	27	25	80	116	126	83
Range, mm.	0.32–0.38	0.49–0.58	0.70–0.91	1.05–1.38	1.46–2.27	2.38–3.66
Mean, mm.	0.35	0.54	0.81	1.27	2.00	3.26

E. pampina overwinters in the litter layer in the egg stage and hatches during the latter part of the following April. Feeding continues until late June or early July. Pupation takes place in the soil in late July or early August and adults begin to emerge near the end of August. Durations of pupation, pupal, and emergence periods are shown in Table I. The flight period lasts from late August to late September. Mating and oviposition take place early in September.

Parasitism

Parasites reared from this host were: *Microplitis confusus* Mues., *Apanteles laeviceps* Ashm., and *Rogas* spp. [Hymenoptera: Braconidae]; *Hyposoter annulipes* Cress.) [Hymenoptera: Ichneumonidae]; *Hypopteromalus* (*tabacum*) (*Fitch*) [Hymenoptera: Pteromalidae].

***Heptagrotis phyllophora* (Grt.)**

Egg and Larva

The egg is circular in outline and semicircular in profile, with dorsoventral striations. When laid it is creamy white but turns brown within two or three days. It has a diameter of 0.7 mm. and a height of 0.5 mm.

Newly hatched larvae are yellowish-green but become brownish before the first moult. There are a white mid-dorsal line, and a white subdorsal line and a white spiracular stripe on each side. The spiracular stripes become a mottled brown in the fourth instar. Full-grown larvae are approximately 25 mm. long and 4.5 mm. wide.

Life-history

The larvae pass through six instars. Head capsule measurements for each instar were as follows:—

Instar	I	II	III	IV	V	VI
No. measured	25	25	25	25	9	10
Range, mm.	0.50–0.56	0.77–0.88	1.09–1.80	1.51–1.80	2.40–2.76	2.87–3.32
Mean, mm.	0.54	0.83	1.19	1.68	2.56	3.09

H. phyllophora overwinters in the soil in the penultimate instar, resumes activity by the middle of April, and feeds for approximately one month before pupating. The duration of the pupal stage is about one month. Phipps (1930), in his study of this species in Maine in 1929 and 1930, reported a mean pupal duration of 16.5 and 19 days respectively. Durations of pupation, pupal, and emergence periods in New Brunswick are shown in Table I. Adults begin to emerge in late June and are in flight throughout July. Mating and oviposition take place shortly after emergence. The incubation period of the egg was not determined. Phipps (1930) stated that eggs of *H. phyllophora* hatched within eight days.

Parasitism

Only one parasite specimen was reared from *H. phyllophora*. It was identified as of *Phryxe pecosensis* (Tns.) [Diptera: Tachinidae].

TABLE I
Durations of Pupation, Pupal, and Emergence Periods of Four Species of Climbing Cutworms

Year	Pupae observed	Pupation period	Pupal period, days		Emergence period
			range	mean	
		Graphiphora smithi (Snell)			
1950	17	June 16–July 27	28–44	31.5	July 30–Aug. 26
1951	6	July 11–24	29–33	30.1	Aug. 13–21
1953	6	July 15–Aug. 3	24–29	27.7	Aug. 13–26
1954	24	June 21–Aug. 12	25–33	29.5	Aug. 7–Sept. 11
1955	9	July 4–18	22–29	25.3	July 26–Aug. 10
1956	5	June 25–July 24	28–35	31.0	Aug. 13–28
		Graphiphora collaris (G.&R.)			
1949	6	June 13–23	61–71	67.2	Aug. 23–Sept. 5
1950	30	June 23–July 30	39–70	49.5	Aug. 20–Sept. 9
1951	24	June 29–July 31	38–66	49.5	Aug. 21–Sept. 8
1954	9	July 6–20	38–56	46.3	Aug. 23–Sept. 4
1955	1	June 30	–	69.0	Sept. 7
1956	4	July 13–30	–	36.0	Sept. 5*
		Eucirrhoedia pampina (Gn.)			
1950	34	July 19–Aug. 8	31–42	36.4	Aug. 25–Sept. 16
1954	6	July 2–Aug. 9	36–39	37.5	Sept. 7
1955	2	July 27–Aug. 9	33–41	37.0	Aug. 29–Sept. 19
		Heptagrotis phyllophora (Grt.)			
1952	1	May 10	–	33.0	June 12
1954	3	May 31	30–32	31.0	June 30–July 2
1955	22	May 23–30	34–38	36.0	June 27–30
1956	23	May 25–June 7	27–37	30.5	July 1–5

*Only one adult emerged.

Summary

The egg and larva of each of the following species of climbing cutworms are described briefly: *Graphiphora smithi* (Snell.), *Graphiphora collaris* (G.&R.), *Eucirrhoedia pampina* (Gn.), and *Heptagrotis phyllophora* (Grt). Parasites are also listed. All these cutworms have one generation a year in New Brunswick and, except *E. pampina*, overwinter in the soil as partially grown larvae. *E. pampina* overwinters in the egg stage. *H. phyllophora* pupates in late May, *G. smithi* and *G. collaris* in late June or July, and *E. pampina* in late July or early August. *H. phyllophora* is in flight in July; the other three species during August and September.

Acknowledgments

The writers are grateful for the many helpful suggestions of Mr. C. W. Maxwell, Officer-in-Charge, Fruit Insect Section, Fredericton, under whose direction the work was carried out, and to Dr. W. R. M. Mason, Dr. O. Peck, Mr. G. S. Walley, Mr. G. E. Shewell, and Mr. C. D. Miller, Entomology Division, Ottawa, for identifying specimens.

References

Lejeune, R. R. 1950. The effect of jack-pine staminate flowers on the size of larvae of the jack-pine budworm, *Choristoneura* sp. *Canadian Ent.* 82:34-43.

Phipps, C. A. 1930. Blueberry and huckleberry insects. *Maine Agr. Expt. Sta. Bull.* 356.

(Received April 29, 1957)

Influence of Adult Food on Viability of Early Stages of *Aptesis basizonia* (Grav.) (Hymenoptera: Ichneumonidae), a Parasite of Pine Sawflies (Diprionidae)[1]

By L. R. Finlayson[2] and Thelma Finlayson[3]
Entomology Laboratory, Belleville, Ontario

It is well known that the reproduction of insects is affected by the nature of the larval and adult foods. However, there seems to be no consistent pattern of adult requirements; possibly this may be due in part to the varying amount of nutrients carried over from the immature stages to the adults of different species. This effect of food upon reproduction is an important factor influencing densities and distributions of insects. Andrewartha and Birch (1954) pointed out that the quality of the food may influence an animal's chance to survive and multiply. Finlayson and Green (1940) found that fecundity of the parasite *Aptesis basizonia* (Grav.) was reduced about 80 per cent and that longevity was drastically shortened when mated females were allowed access to water but not food. Indirect factors may also be responsible. Allen and Selman (1955) showed that there was a significant reduction in egg production of the mustard beetle, *Phaedon cochleariae* (F.), when fed on leaves deficient in nitrogen, phosphorus, potassium, or iron. Soils with such deficiencies might account for local variations in the density and distribution of insect species. Evans (1938) found that lack of light influenced the amount of protein in cabbages and ultimately reduced the number of young of *Brevicoryne brassicae* (L.) by about two-thirds. The effect of food on viability is of secondary importance, but should be investigated in any study of reproduction.

Aptesis basizonia, a hymenopterous parasite of *Diprion pini* (L.), *Diprion similis* (Htg.), *Neodiprion sertifer* (Geoff.), and other species of Diprionidae in Europe, has been propagated at the Belleville laboratory for release in biological control programs and for use as an experimental animal. It was observed that hatching of the eggs and survival of the young larvae of *A. basizonia* decreased with increasing age of the females. In most instances where mortality occurred the embryos completed development and frequently eclosion took place, but the hatching larvae were unable to establish themselves upon the host. That development progressed to this extent indicated that the mortality was not caused by mechanical damage. Experiments were carried out to discover whether the mortality was caused by inadequacy in the adult diet and, if so, how viability could be increased.

Materials and Methods

Each female was placed in a small box, food being provided by a raisin with broken surface and moisture by absorbent cotton moistened with water. One host cocoon was supplied to the female every second day. On the succeeding day the cocoon was opened and any eggs that had been laid were removed and counted. The eggs were then transferred to freshly opened cocoons of *Neodiprion lecontei* (Fitch), one egg to each cocoon. This is a modified version of the method described by Green (1938). Some "collapsed" eggs occurred, as were noted by Rosenberg (1934) in *Ephialtes extensor* Tasch. and by Simmonds (1948) in *Cryptus inornatus* Pratt. These were thought to be mechanically injured by the female after oviposition. Only undamaged eggs were transferred to cocoons, and the collapsed eggs were not included in the estimates of viability.

Thirty-four females were handled in this way for 33 days after emergence. Up to that time members of the former group averaged 34.4 eggs per female and

[1]Contribution No. 3543, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
[2]Assistant Entomologist.
[3]Technical Officer.

those of the latter group 35.9 eggs per female. Student's *t* test showed that there was no significant difference in the oviposition of the two groups at the one per cent level. It may be assumed, therefore, that the two groups were of the same population up to the end of the 33rd day. Then they were divided into two groups, one being continued to be fed on raisins and the other on fresh, unpasteurized honey. Otherwise the two groups were treated in an identical manner. The host cocoons containing the transferred eggs were incubated for four weeks at 20-21°C., which is usually adequate for complete development of the parasites. The host cocoons were then inspected to find how far the parasites had developed. A microscopic examination was made of each specimen in which development was incomplete.

Results

From the 33rd day until the end of the experiment, when all the females were dead, the group that was still being fed on raisins produced 86 eggs, those fed on honey, 201. Student's *t* test showed that the number of eggs produced by the group that was fed on honey was significantly greater at the one per cent level than the number produced by the group fed on raisins.

Longevity of the females was not increased by changing the food from raisins to honey, the raisin-fed females having a slightly greater average length of life.

Table I shows that for aging females fed on honey the number of larvae that developed was 22.4 per cent of the number of eggs laid, in comparison with 4.7 per cent for those fed on raisins (about 5:1). The ratio is 11:1 on the basis of the number of females.

Discussion and Conclusions

The experiments indicate that the decrease in viability of progeny of aging females of *A. basizonia* may be related to the nature of the adult food. The most likely reason for this is that the young adult may possess a substance or complex of substances derived from its host during larval feeding that may be gradually depleted with continued oviposition. This is supported by the fact that contents of the first-laid eggs are yellowish in colour, whereas the contents of eggs laid later are pearly-white, indicating a change of some sort as the female ages. It is not suggested that there is any relationship between the colour and the viability, but rather that unknown substances may be transferred to the egg by the younger but not by the older females. The fecundity of several species is known to be affected by the quality of larval feeding, but references to the effect of food on viability are few. Norris (1933) noticed a reduced fecundity in *Ephestia kühniella* Zell. but no reduction in viability when white flour instead of wholemeal flour was used as larval food. In *A. basizonia* there was a resurgence of viability when honey was supplied to the adult after feeding on raisins. The availability of protein seems unlikely to be a factor, as the adult female does not feed upon the host as do some other species of parasitic Hymenoptera, and as both raisins and honey contain protein in the proportion of about 8 to 1 (anon., 1954). Work on birds in recent years by Carpenter and Duckworth (1954), Shultz, Grau, and Zweigart (1953), Csonka, Lillie, and Martin (1954), and Bentley and Hershberger (1954) has shown that an "animal protein factor" (of which vitamin B12 is a part) corrects reproductive problems such as loss of viability that result from an all-vegetable diet. The vitamin values of raisins are low (Sun Maid Raisin Growers of California, in litt.) and, as raisins are of vegetable origin, the possibility of their containing vitamin B12 may be ruled out. Various honeys, however, were assayed for the authors by officers of the Bacteriology Division, Science Service, Ottawa, and vitamin B12

B & Z LIBRARY

TABLE I

Survival and development of progeny of females of *Aptesis basizonia* (Grav.) fed on two foods after having been fed on raisins for 33 days

Progeny	From 17 females fed on raisins		From 17 females fed on honey	
	Number	Per cent	Number	Per cent
Eggs laid	86	100.0	201	100.0
Undamaged eggs used in experiment	80	93.0	188	93.5
Eggs showing no development	26	30.2	32	15.9
Embryos developing only to eclosion	50	58.1	104	51.7
Larvae that died after some feeding	0	0	7	3.5
Larvae that spun cocoons	4	4.7	45	22.4

active substances were found in all. As the results of the experiment with *A. basizonia* resemble those with birds, it may be that vitamin B12 or a related substance is one of the agents responsible for increasing the viability of the eggs and survival of the early stages of this insect.

Summary

Aging adult females of *Aptesis basizonia* (Grav.) fed on honey laid more eggs and their progeny showed greater viability than when females were fed on raisins. This suggested that the difference may be caused by the presence in honey of some substance similar to vitamin B12.

Acknowledgment

The authors wish to thank Dr. A. G. Lochhead, former Chief, Bacteriology Division, Science Service, Ottawa, for arranging to have the samples of honey tested for the presence of vitamin B12.

References

Allen, M. D., and I. W. Selman. 1955. Egg production in the mustard beetle *Phaedon cochleariae* (F.) in relation to diets of mineral deficient leaves. *Bull Ent. Res.* 46:393-397.

Anonymous. 1945. Tables of food composition in terms of eleven nutrients. *U.S. Dept. Agr. Misc. Pub. No.* 572.

Andrewartha, H. G., and L. C. Birch. 1954. The distribution and abundance of animals. *University of Chicago Press, Chicago.*

Bentley, O. G., and T. V. Hershberger. 1954. The effect of antibiotics on hatchability of hens' eggs and progeny growth performance. *Poultry Sci.* 33:641-648

Carpenter, K., and J. Duckworth. 1954. Animal protein for poultry and pigs. *British Agr. Bull.* 21:165-170.

Csonka, F. A., R. J. Lillie, and W. Martin. 1954. The maternal diet as a source of growth factors transmitted by the hen through the egg to the progeny. *J. Nutrition* 52:285-296.

Evans, A. C. 1938. Physiological relationship between insects and their host plants. I. The effect of the chemical composition of the plant on reproduction and production of winged forms in *Brevicoryne brassicae* L. (Aphidae). *Ann. Appl. Biol.* 25:558-572.

Finlayson, L. R., and T. Green. 1940. A note on the effect of certain foods upon fecundity and longevity in *Microcryptus basizonius* Grav. (Hymenoptera). *Canadian Ent.* 72: 236-238.

Green, T. U. 1938. A laboratory method for the propagation of *Microcryptus basizonius* Grav. *69th Ann. Rept. Ent. Soc. Ontario*, 1938, pp. 32-34.

Norris, M. J. 1933. Contributions towards the study of insect fertility. II. Experiments on the factors influencing fertility in *Ephestia kuhniella* Z. (Lepidoptera, Phycitidae). *Proc. Zool. Soc. London*, 1933, pp. 903-934.

Rosenberg, H. T. 1934. Biology and distribution in France of the larval parasites of *Cydia pomonella* L. *Bull. Ent. Res.* 25:201-256.

Shultz, F. T., C. R. Grau, and P. Zweigart. 1953. Studies in pigeon nutrition. *California Agr.* 7:14-15.

Simmonds, F. J. 1948. The biology of parasites of *Loxostege sticticalis* L. in North America. IV: *Cryptus inornatus* Pratt (Ichneumonidae, Cryptinae). *Proc. Roy. Ent. Soc. London* (*A*) 23: 71-79.

Parasites of *Hylemya* spp. (Diptera: Anthomyiidae) That Attack Cruciferous Crops in Europe[1]

By Geo. Wishart[2], E. H. Colhoun[3], and A. Elizabeth Monteith[4]
Entomology Laboratory, Belleville, Ontario

Wishart (in press) reported on surveys of parasites of the species of *Hylemya* that attack cruciferous crops in Canada. A similar survey was carried out in Europe during 1949 to 1954 to determine whether there were parasites not already present in Canada that, if introduced and established, might aid in the control. Some data gathered in this survey were published previously (Wilkes and Wishart, 1953; Wishart and Monteith, 1954).

In Europe, as in Canada, the two chief pest species are *H. brassicae* (Bouché) and *H. floralis* (Fall.). *H. cilicrura* (Rond.) and *H. trichodactyla* (Rond.) (= *H. fusciceps* (Zett.) and *H. florilega* Zett. of Lundblad, 1933, respectively) are also present. The species of plants attacked are largely the same as in Canada except that a greater variety of crops suffer damage, probably because a greater variety of crops are grown. *H. brassicae* and *H. cilicrura* occur everywhere in western Europe. *H. floralis*, as in Canada, is confined to the more northerly parts of the Continent. It has been recorded from Germany, Holland, and Austria, but in the large collections made in this survey was not found south of Denmark on the Continent or south of Scotland in Great Britain.

No comprehensive study of the parasites of *Hylemya* spp. in western Europe had been made previously. Some workers (Wadsworth, 1915; Lundblad, 1933; de Wilde, 1947) investigated the parasites in limited areas or included observations on parasites in their investigations of problems of other aspects of the maggots. Some inaccuracies are now evident in this early work. This is understandable and our own work was not entirely free from them in its early stages. One source of inaccuracy is the difficulty of identification of parasites and of hosts, especially when synonomy is involved. Another is that of avoiding the false results obtained when collected hosts are reared in bulk. Lundblad (1933, p. 73) recognized this: "Some of the species mentioned have not, however, with absolute certainty been reared from cabbage flies but may have come from other flies that have been included in the rearing departments". Until recently, keys to *Hylemya* spp. have stressed or included only adult characters. When a parasite emerges there is no host fly to identify and without keys to the immature stages inaccuracies are likely to occur.

The following parasites have been recorded on *H. brassicae* or *H. floralis* or both from Europe:—

Hymenoptera

Braconidae

Taphaeus conformis Wesm. = *Diospilus oleraceus* Hal.	(Shutze and Roman, 1931)
Dacnusa straminipes Hal.	(Lundblad, 1933)
Opius procerus Wesm.	(Picard, 1930)
Aphaereta minuta Nees	(Bremond, 1937)
A. difficilis Nees	(Nixon, 1939)

Ichneumonidae

Stilpnus gagates Grav.	(Vodinskaya, 1928)
Phygadeuon fumator (Grav.)	(Wadsworth, 1915)
Atractodes tenebricosus Grav.	(Wadsworth, 1915)

[1]Contribution No. 3546, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
[2]Entomologist.
[3]Entomologist; now at Science Service Laboratory, London, Ontario.
[4]Technical Officer; now Mrs. F. C. Hayes, 269 Soudan Avenue, Toronto.

Cynipidae	
Trybliographa rapae (Westw.)	(Lundblad, 1933; de Wilde, 1947)
Trybliographa gerasimovi (Meyer)	(Meyer, 1926)
Psichacra spinosa (Htg.)	(Vasina, 1927)
Figitidae	
Figites anthomyiarum Bouché	(Fahringer, 1921)
Coleoptera	
Staphylinidae	
Aleochara bilineata Gyll.	(Wadsworth, 1915; de Wilde, 1947; Lundblad, 1933)
A. bipustulata (L.)	(de Wilde, 1947)

Materials and Methods

In 1949 officers of the Commonwealth Institute of Biological Control collected and sent to Canada approximately 26,000 puparia of *Hylemya* spp., mostly *H. brassicae*. In 1950 the senior author collected in France, Belgium, Holland, Denmark, Sweden, Norway, Scotland, and England. In 1951, Dr. E. H. Colhoun investigated the maggots and their parasites in Holland and made extensive collections there and in Scotland. Similar investigations were carried out and puparia collected in Norway in 1952 and 1953. Collections were made in Finland in 1954. In addition, European entomologists co-operated by sending to the Belleville Laboratory collections of *H. brassicae* and *H. floralis* from 1951 to 1953.

Part of the 1949 collections from Switzerland were reared, at Belleville, individually and part in bulk. The collections made in 1950 were reared in bulk in Switzerland. From 1951 to 1954 all rearing was done at Belleville and all puparia were handled individually in vials. These were kept at 75°F. and 80 per cent relative humidity. Each day the emerged hosts and parasites were removed and recorded; where identifications could not be made locally, the specimens were sent to the Entomology Division, Ottawa. All hosts, both parasitized and unparasitized, were identified from the puparia with the aid of Brooks' (1949, 1951) keys. Hymenopterous parasites from the 1950 collections were identified by Dr. C. Ferrière, Museum d'Histoire Naturelle, Geneva.

Results and Discussion

The numbers of puparia of the various host species collected in the various countries are given in Table I. To present accurate data on the relative abundance of the various host species, collections should have been made throughout the season in all areas. Only in Holland in 1951 and in Norway in 1952 was this possible. Where collections of *H. brassicae* were made only once, only one generation, usually the first, was represented. Where *H. brassicae* and *H. floralis* both occur, early collections consisted almost entirely of *H. brassicae* and late collections of *H. floralis*. *H. cilicrura*, usually present with the two pest species, is included because it is a host of the same parasites as the pest species; it was not collected from its main host plants.

Tables II to IV show the distributions and relative abundance of the three major parasites, *Aleochara bilineata*, *Trybliographa rapae*, and *A. bipustulata*. Several other species were recorded in small numbers, namely, *Phygadeuon trichops* Thoms. from *H. brassicae* from Switzerland, Scotland, and Norway; *P. fumator* (Grav.) from *H. brassicae* from France; *Phygadeuon* sp. from *H. brassicae* from Holland, Norway and Finland and from *H. floralis* and *H. cilicrura* from Norway and Finland; *Aphaereta difficilis* Nees from *H. brassicae* from

TABLE I

Numbers of puparia of *Hylemya* spp. collected in various countries of Europe, 1949–1954

	H. brassicae						*H. floralis*				*H. cilicrura*				
	1949*	1950*	1951	1952	1953	1954	1951	1952	1953	1954	1951	1952	1953	1954	Total**
Switzerland	25,877														25,877
France		3,484													3,484
Belgium		2,081													2,081
Holland		4,431	16,131								648				21,390
Denmark		112	67				2,098								2,277
Sweden		242		135				1,350				1			1,728
Finland						5,287				6,367				154	11,808
Norway		96	1,327	20,444	3,631		4,712	18,321	9		49	358	138		49,085
Scotland		1,174	647				706				1				2,528
England		1,158													1,158
Total	25,877	12,778	18,352	20,579	3,631	5,287	7,516	19,671	9	6,367	698	359	138	154	121,416

H. brassicae and *H. cilicrura*, mostly *H. brassicae*.
**The totals for the species are respectively 86,504, 33,563, and 1,394.

TABLE II

Percentages of three species of *Hylemya* parasitized by *Aleochara bilineata* Gyll. in western Europe, 1949–1954

	H. brassicae						*H. floralis*				*H. cilicrura*			
	1949*	1950*	1951	1952	1953	1954	1951	1952	1953	1954	1951	1952	1953	1954
Switzerland	1–17													
France		4–65												
Belgium		33												
Holland		5–58	1–39								0–48			
Denmark		74	0				0							
Sweden		83												
Finland						0–41				1–33				0–25
Norway		0	2– 6	2–21	0–25		0– 6	1– 8	17–50		0–13	0–83	8–26	
Scotland		2–44	1–10											
England		2												

*As *H. brassicae* and *H. cilicrura* were reared in bulk in 1949 and 1950, the figures are totals for the two species.

TABLE III

Percentages of three species of *Hylemya* parasitized by *Trybliographa rapae* (Westw.) in western Europe, 1949–1954

	H. brassicae						*H. floralis*				*H. cilicrura*			
	1949*	1950*	1951	1952	1953	1954	1951	1952	1953	1954	1951	1952	1953	1954
Switzerland	5–12													
France		1–10												
Belgium		22												
Holland		6–13	2–34								0–67			
Denmark		3	0– 3				0– 7							
Sweden		5		8								3		
Finland						0–63				0–89				0–58
Norway		17	0–24	0–29	0– 6		13–39	0–93	0		0–76	0–50	0–17	
Scotland		0– 3	0–18				5–50							
England		13												

*As *H. brassicae* and *H. cilicrura* were reared in bulk in 1949 and 1950, the figures are totals for the two species.

TABLE IV
Percentages of three species of *Hylemya* parasitized by *Aleochara bipustulata* (L.) in western Europe, 1950–1953

	H. brassicae				*H. floralis*			*H. cilicrura*		
	1950*	1951	1952	1953	1951	1952	1953	1951	1952	1953
France	1–10									
Belgium	1									
Holland	1– 2	0– 3						0–21		
Denmark	3									
Sweden										
Norway		0	0– 1	0	**	0	0	0	**	0
Scotland	2–41	3								
England	3									

*As *H. brassicae* and *H. cilicrura* were reared in bulk in 1950, the figures are totals for the two species.
**One individual.

France; *A. tennuicornis* Nix. from *H. brassicae* from Finland; *Psilus* sp. (Proctotrupoidea) from *H. floralis* from Finland; *Alysia manducator* Panz. from *H. floralis* from Norway; and *Loxotropa tritoma* (Thoms.) from *H. brassicae* from Holland.

A. bilineata was found almost everywhere and on all three hosts. The life-history of this species was described by Wadsworth (1915) and Colhoun (1953). As it can attack the puparia during the whole period they are in the soil and as the collections were made at various times in this vulnerable period, records for percentage parasitization by this species are to varying degrees below the actual.

The life-history of *T. rapae* was described by Wishart and Monteith (1954). As this parasite attacks the larval stages and emerges from the puparia later than the host, any fair sample of puparia contains a fair sample of the parasite. The highest percentages of parasitization by this species were found in Norway and Finland, on *H. floralis*. The dependence of *T. rapae* on *H. brassicae* as an early-season host was mentioned in an earlier paper (Wishart, in press). Where *H. brassicae* is not found there is little or no parasitization of *H. floralis* by *T. rapae* (e.g., in Manitoba and Saskatchewan, Canada, and Hokkaido, Japan). In Norway and Finland *H. brassicae* is abundant in the spring and provides hosts for a generation of *T. rapae*, the adults of which are in the field at a time when they can attack large numbers of *H. floralis*.

Of the lesser parasites, *Phygadeuon* spp. are by far the most abundant and widely distributed. The life-history of *P. trichops* was described by Monteith (1956). In the laboratory it attacks the three species of *Hylemya* mentioned above and also *H. antique* (Mg.), but its general scarcity where these hosts are abundant indicates that in the field it attacks them only in the absence of more favoured hosts. Laboratory-reared adults of *P. trichops* were released in Canada where *Hylemya* spp. were abundant but there was no indication of establishment.

Aleochara bilineata, *A. bipustulata*, and *T. rapae* are present in Canada in numbers comparable to those found in Europe (Wishart, in press). None of

these has been recorded from hosts, other than the pest species, in North America; their presence here must, therefore, be considered to be closely related to the presence of the hosts. The cabbage maggot, *H. brassicae*, was stated by early workers (Schoene, 1916; Gibson and Treherne, 1916) to have been introduced from Europe. Schoene (loc. cit). stated also that all the plants attacked by *H. brassicae* were of European origin. Brown (1940) stated that two criteria should be employed in assessing whether a species is introduced: the known history and the distributional patterns. He (1950) stated further that "erratic or immature distributional patterns shown by numerous species [of Coleoptera] are evidence that they are introduced" and also (1940) "the great majority of truly holarctic species have a transcontinental distribution in northern United States or in Canada". If introduced, *H. brassicae* was established before there was much formal entomological observation, unlike the European corn borer, the spread of which was observed almost from its introduction. In spite of its long presence here, the distributional pattern of *H. brassicae* is still immature; only recently has it been reported from Saskatchewan and there are still no records from Manitoba. *H. floralis* is still absent from the Maritime Provinces, an environment similar to that in which it is most abundant in Europe. If it is accepted that the pest species were introduced, it is obvious that the parasites were also introduced, probably in the same manner and at the same time as the principal host, *H. brassicae*.

Summary

Surveys for parasites of *Hylemya brassicae* (Bouché) and *H. floralis* (Fall.) in 10 countries of western Europe showed that the staphylinids *Aleochara bilineata* Gyll. and *A. bipustulata* (L.) and the cynipid *Trybliographa rapae* (Wesw.) were widely distributed, *A. bilineata* and *T. rapae* in considerable numbers. As previously unrecognized synonomy was discovered, the number of parasitic species is smaller than recorded before. The incidence of attack by the chief species was comparable to that in Canada.

Acknowledgments

The contribution to this project by systematists of the Entomology Division, Ottawa, is gratefully acknowledged, particularly that of Mr. W. J. Brown, Dr. Oswald Peck, Mr. G. S. Walley and Dr. Wm. R. M. Mason in identifying parasites and Mr. J. G. Chillcott and Mr. J. F. McAlpine in identifying hosts.

The work in Europe was greatly facilitated by co-operation of many entomologists and horticulturists in locating infestations, in arranging for permission to collect, and in some cases in making collections, particularly the following: Dr. Bernard Trouvelot, Station Centrale de Zoologie Agricole, Versailles, France; Professor J. van den Brande, Rijksandbouwhogeschool, Ghent, Belgium; Dr. R. J. de Fluiter, Institute for Phytopathological Research, Wageningen, Holland; Mr. A. van Herwijnen, Phytopathological Service, Sint Pancras, Holland; Dr. Prosper Bovien and Mr. Ole Wang, Statens Plantepotologiske Forsg, Lyngby, Denmark; Fil. lic. Edward Sylven, Vaxtskyddsanstatten, Akarp, Sweden; Dr. Arne Johansson, University of Oslo, Norway; Mr. Joc Fjelddalen, Norwegian Plant Protection Unit, Oslo, Norway; Dr. Guy Morison and Mr. Milton Shaw, Marischal College, Aberdeen, Scotland; Dr. D. S. MacLagan, West of Scotland Agricultural College, Glasgow; Mr. Ian Walls, Horticultural Advisor, Glasgow; Mr. A. B. Webster, Horticultural Advisor, Ayr, Scotland; Mr. D. W. Wright, National Vegetable Research Station, Wellsbourne, Warwick, England; Mr. D. C. Thomas, Entomological Advisor, Starcross, Devon; and Mr. S. P. Craze, Horticultural Advisor, Penzance, England.

Mention should also be made of assistance given by Dr. Louis P. Mesnil, Commonwealth Institute of Biological Control, Feldmeilen, Switzerland, who was responsible for rearing the collected insects in 1950, and Messers Werner Mueller, C. D. Putnam, M. Locke and A. W. R. McCrae, temporary employees of the Entomology Division who were engaged in collecting host insects.

The assistance of all these is gratefully acknowledged.

References

Bremond, P. 1937. Observations sur *Chortophila brassicae* Bché. et son parasite *Aphaereta minuta* Nees au Maroc. *Rev. Path. Veg.* 24.

Brooks, A. R. 1949. The identification of the commoner root maggots of garden crops in Canada. *Canada Dept. Agr., Div. Ent. mimeographed pamphlet.*

Brooks, A. R. 1951. Identification of root maggots (Diptera: Anthomyiidae) attacking cruciferous garden crops in Canada, with notes on biology and control. *Canadian Ent.* 83: 109-120.

Brown, W. J. 1940. Notes on the American distribution of some species of Coleoptera common to the European and North American continents. *Canadian Ent.* 72: 65-78.

Brown, W. J. 1950. The extralimital distribution of some species of Coleoptera. *Canadian Ent.* 82: 197-205.

Colhoun, E. H. 1953. Notes on the stages and the biology of *Baryodma ontarionis* Casey (Coleoptera: Staphylinidae), a parasite of the cabbage maggot, *Hylemya brassicae* Bouché (Diptera: Anthomyiidae). *Canadian Ent.* 85:1-6.

de Wilde, J. 1947. Over enkele belengwekkende parasieten van de koolvleig, *Chortophila brassicae* Bché. *Tijdschr. Ent.* 88: 531-536.

Fahringer, J. 1921. Beiträge zur Kenntnis der Lebensweise einiger Schmarotzerwespen unter besonderer Berücksichtigung ihrer Bedeutung für biolog Bekämpfung von Schädlingen. *Zeits. angew. Ent.* 8: 325-388

Gibson, A., and R. C. Treherne. 1916. The cabbage root maggot and its control in Canada. *Canada Dept. Agr., Ent. Br. Bull.* 12.

Lundblad, O. 1933. Kalflugorna. Statens Växtskyddanstalt, Medd. 3.

Meyer, N. F. 1926. Einige neue Ichneumoniden und Cynipiden. *Rev. Russe Ent.* 20: 260-264.

Monteith, A. Elizabeth. 1956. *Phygadeuon trichops* Thoms. (Hymenoptera: Ichneumonidae), an occasional parasite of *Hylemya* spp. (Diptera: Anthomyiidae). *Canadian Ent.* 88: 69-73.

Moltschanova, O. P. 1930. Zur Biologie von *Cothanaspis rapae* West., des Parasiten der Kohlpiege (*Hylemya brassicae* Bouché) (summary in German). *Rept. Bur. Appl. Ent.* 4: 365-370.

Nixon, G. E. J. 1939. Notes on the Alysiinae with descriptions of three new species. *Proc. Roy. Ent. Soc. London, B,* 8: 61-67.

Picard, O. 1930. Les insectes du chou. *Prog. agr. vitic.* 44: 473-479.

Schoene, W. J. 1916. The cabbage maggot: its biology and control. *New York Agr. Expt. Sta. Bull. No.* 419.

Schutz, K. T., and A. Roman. 1931. Schlupfwespen *Isis Budissina* (*Bautzen*) Bd. 12 reprint (10 pp.).

Vasina, A. N. 1927. The cabbage fly (*Hylemyia brassicae*, Bch., and *H. floralis*, Fall.) [in Russian]. *Trud. Opuitno-Issled. Uchastka Stantz. Zashch. Rast. Vred. Mosk. Zemel. Otd.* pt. 1: 63-89. *Rev. Appl. Ent., A,* 16: 412-414. 1928

Vodinskaya, K. I. 1928. On the biology and ecology of *Hylemya brassicae* Bché. and H. floralis Fall. *Rept. Bur. Appl. Ent.* 3: 229-249.

Wadsworth, J. T. 1915. On the life-history of *Aleochara bilineata* Gyll., a staphylinid parasite of *Chortophila brassicae* Bouché. *J. Econ. Biol.* 10: 1-27.

Wadsworth, J. T. 1915. Notes on some hymenopterous parasites bred from the pupae of *Chortophila brassicae* Bouché and *Acidia heraclei* L. *Ann. Appl. Biol.* 2: 158-161.

Wilkes, A., and G. Wishart. 1953. Studies on parasites of root maggots (*Hylemya* spp.; Diptera: Anthomyiidae) in the Netherlands in relation to their control in Canada. *Tijdschr. Plantenziek.* 59: 185-188.

Wishart, G. Surveys of the parasites of the species of *Hylemya* (Diptera: Anthomyiidae) that attack cruciferous crops in Canada. *Canadian Ent.* (in press)

Wishart, G., and Elizabeth Monteith. 1954. *Trybliographa rapae* (Westw.) (Hymenoptera: Cynipidae), a parasite of *Hylemya* spp. (Diptera: Anthomyiidae). *Canadian Ent.* 86: 145-154.

A Theory of Olfaction and of the Action of Mosquito Repellents

By R. H. WRIGHT
Head, Division of Chemistry, British Columbia Research Council
Vancouver 8, Canada

Introduction

To produce an odor sensation, a substance must be volatile and its molecules must come into contact with the olfactory end organ, which may require some measure of lipoid solubility. This much is generally agreed, but beyond this there has been no accepted theory of the triggering process by which the odorous molecule initiates a discharge of the olfactory nerve. In part, this ignorance has been due to the lack of any secure correlation between the odors of substances and the chemical constitution or reactivity of the odorous molecules, or their physical shapes or electrical properties. A correlation of odor with molecular vibrational modes would be consistent with most of the facts of olfactory chemistry, but this hypothesis has failed to win general acceptance up till now because, (1) there has been no direct evidence of a correlation between odor and vibrational frequency, and, (2) there has been no suggestion of a mechanism whereby a molecular vibration could trigger a nervous discharge. Some evidence bearing on both these objections has recently been brought forward which is of considerable interest in relation to the problem of insect attractancy and repellency (7, 8, 9, 10, 11).

Molecular Vibration

In general, a molecule composed of n atoms will have (3n-6) fundamental vibrational modes, or (3n-5) modes if the molecule is linear. These vibrational movements can be set in motion by intermolecular collisions of sufficient violence, but in common with other molecular and atomic vibrational processes they are subject to certain quantum restrictions.

These restrictions amount to a requirement that each vibrational mode requires a certain finite minimum amount of energy to activate it, and if a molecular collision is not violent enough to supply this energy, the vibrational mode will not be activated. The minimum activating energy is one quantum and its magnitude depends on the frequency of the vibrating system, through the formula,

$$E = h\nu$$

where, E is the minimum energy to excite the vibration; h is a universal constant, (Planck's Constant); and v is the frequency of the vibrating system.

In a complex molecule there are many vibrational modes, each with its own characteristic frequency, so that some of the vibrational modes will have low frequencies and be easily excited whereas others will have higher frequencies and be excited only by particularly violent molecular collisions. The mean violence of intermolecular collisions depends upon the temperature and is greater at high temperatures than at low. Thus the average energy of a molecular vibrational mode will depend on the interplay of two factors, namely, the frequency of the mode and the temperature. The precise state of affairs is described by Planck's formula:

$$\overline{U}_{\nu T} = \frac{h\nu}{e^{h\nu/KT} - 1}$$

where, $\overline{U}_{\nu T}$ is the mean energy of an oscillator of frequency v and at a temperature T°K; e is the base of natural logarithms; and k is the gas constant for one molecule (Boltzmann's Constant).

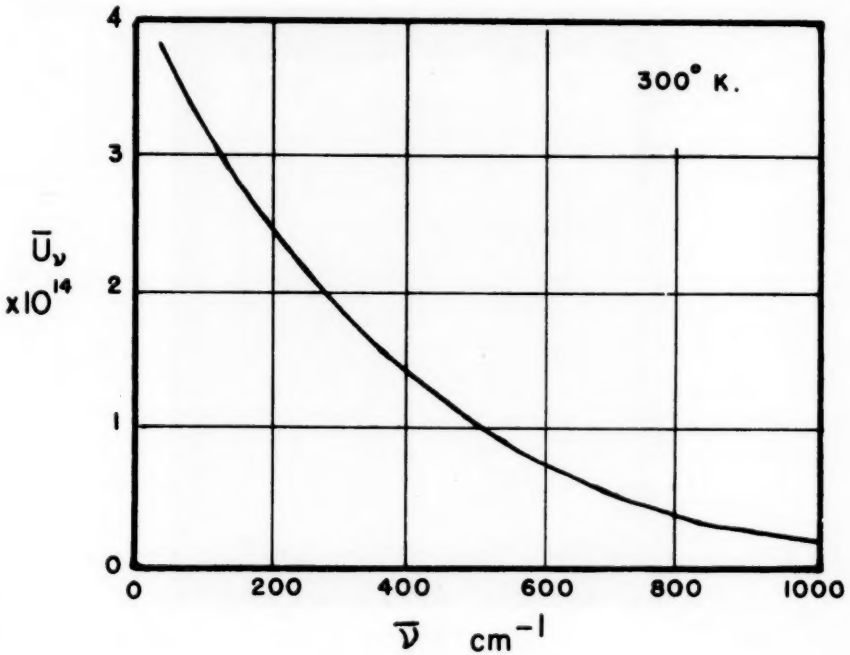


Figure 1

Figure 1 shows the energy as a function of frequency for oscillators activated by collision in a system at a temperature of 300°K., which is near that of the bodies of most living creatures. It is evident that only the low frequency vibrations, below about 700 cm^{-1}, are active to any significant degree under these conditions.

Molecular vibrations of the sort being considered here can be studied experimentally through the Raman effect or by observations of the infrared absorption spectrum of a substance. The Raman effect is experimentally difficult to study but has been applied quite extensively to the study of molecular vibrations, especially those of higher frequency, usually above 800 or 1000 cm^{-1}. Infrared spectra have also been extensively studied in the higher ranges of frequency, but until quite recently instrumental difficulties have stood in the way of easy observations of what may be termed the "olfactory frequencies" below 600 or 700 cm^{-1}. However, some evidence of correlation between odor and low frequency vibrational modes has been put forward (9, 11). Low frequency molecular vibration as the physical basis of odor has, therefore, something more than an *a priori* plausibility.

The Triggering of Olfactory Sensations

Turning now to the triggering mechanism at the olfactory end organ, the problem is to conceive of a process by which the near approach of a molecule vibrating with a particular frequency could bring about a depolarization of the wall of the nerve cell, which is *ex hypothesi* sensitive to that particular frequency.

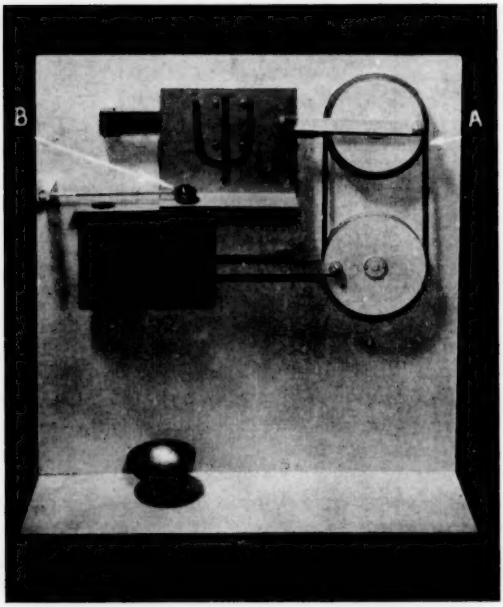


Figure 2

The mechanism which has been proposed (10) refers primarily to olfaction in the higher vertebrates, but as olfaction is one of the most primitive senses it is not unlikely that a generally similar mechanism could be operative in insects. One important difference, however, lies in the fact that in the higher vertebrates the sensory end organ is covered by a muco-lipid fluid, whereas the olfactory end organs of insects are dry (2).

The nerve cells of the olfactory end organ are known to contain a pigment, though its constitution is unknown. The fact that it is colored shows that the olfactory pigment has weakly bound electrons which can be raised to an excited state metabolically or by other means. De-excitation of the pigment molecule and the return of the electron to its ground state may occur easily, in which case the transition is said to be "allowed", or it may take place only after some delay, in which case it is "forbidden". The transition is forbidden if a function called the transition moment integral is zero or at least very small, i.e., if

$$\int_{-\infty}^{+\infty} \psi_U^* \, M \, \psi_L \, d\tau = 0$$

In this expression, ψ_U^* and ψ_L are the wave functions of an electron in the pigment in its upper or excited state, and in its lower or ground state respectively. The expression will be zero if one of these wave functions is zero whenever the other is finite, and *vice versa*, i.e. if there is no "overlap" between the two functions. In general, this requires that the two wave functions be *and remain* 180° out of phase.

This can be illustrated by a mechanical analogue shown in Figure 2. The two wave functions are represented by metal plates which are caused to move

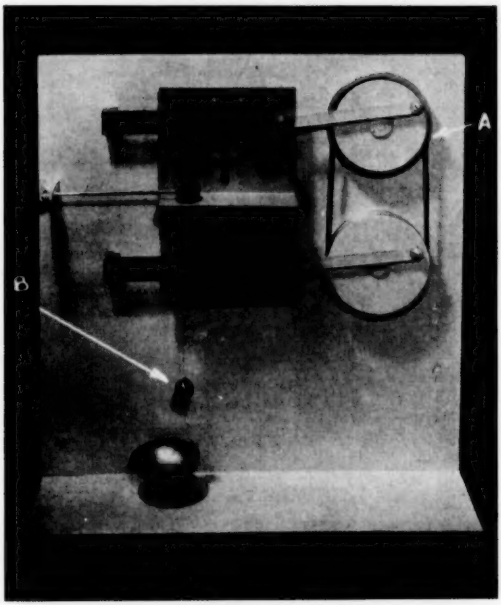


Figure 3

back and forth by cranks which are connected together by pulleys of the same diameter (A) and which therefore oscillate with exactly the same frequency. If the metal plates have each a hole so placed that a steel ball (B) can fall through only when the two plates are at the same extreme of their motion at the same time, i.e. when they are in phase, then so long as the condition represented by the apparatus in Figure 2 exists, the fall of the steel ball will be prevented by the absence of "overlap" between the two wave functions. If, however, the size of one of the pulleys is altered, as shown at A in Figure 3, so that the two oscillators no longer have the same frequency, then as they move back and forth, the faster oscillator will run ahead of the slower and the oscillators will pass in and out of phase, or there will be "beats" between them. Whenever the beats bring the two oscillators into phase, the return of the steel ball to the lower level will be "allowed". (B in Fig. 3).

The normal, waiting, sensitive state of the olfactory end organ is pictured as corresponding to the condition represented by Figure 2, with the pigment molecules electronically excited and the return to the ground state forbidden. When an odorous molecule whose vibrational frequency matches that of the pigment molecule becomes linked to it by forces of adsorption, or something of the sort, the frequency of vibration of the combined system pigment-plus-odorous-molecule is not the same as the frequency of the pigment alone or the odorous molecule alone, even though these two frequencies are identical when they are not linked to each other. This is a general property of vibrating systems and can be demonstrated very easily with pendula or weights supported on springs, or in other ways.

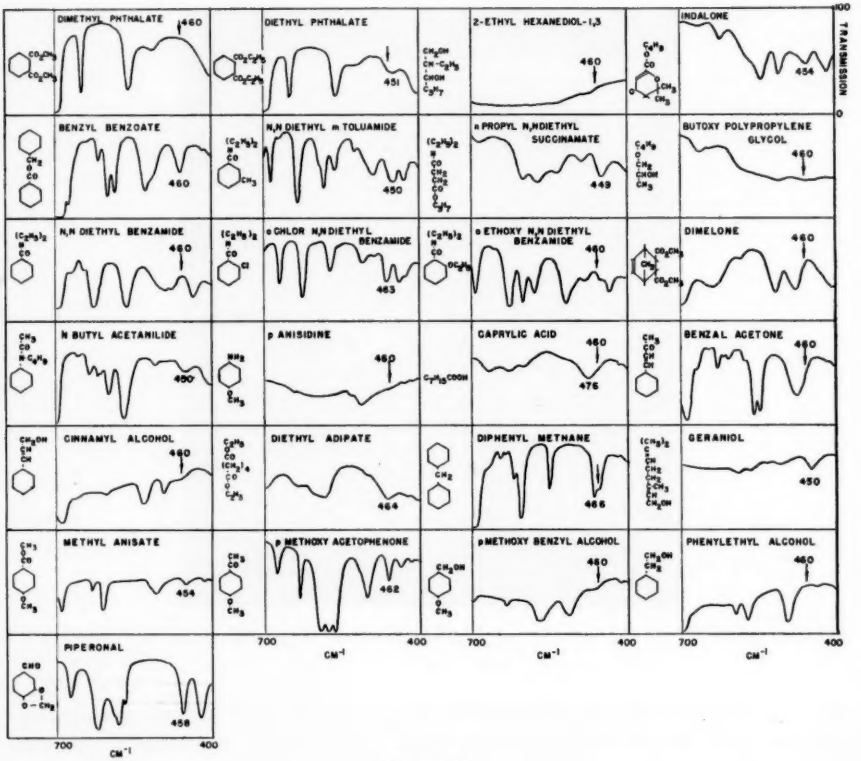


Figure 4

Thus it is relatively easy to conceive of the vibrations of odorous molecules as initiating a nervous discharge, provided the cell membrane of the olfactory end organ contains a substance with rather special but by no means unprecedented properties.

The mechanism postulates a plurality of end organs sensitive to a number of different vibrational frequencies. If there are N kinds of end organ there will be 2^N possible combinations or the possibility of discriminating 2^N different odors. Hainer, Emslie and Jacobson (4) have suggested that in Man, N is of the order of 24, which suggests that we may be able to discriminate as many as 16,000,000 odors. In insects, N is probably much smaller and may even be as low as 1 in some species.

Thus the theory requires that:

The *possession of an odor* by a particular substance will depend on its having the necessary volatility (and lipoid solubility?), together with a certain low frequency mode or modes of vibration;

The *type of odor* will depend on the particular frequency or combination of frequencies of the vibrational modes;

The *odor threshold concentration* (i.e. the minimum amount of odorous material required to produce an odor sensation) will depend on the closeness of the

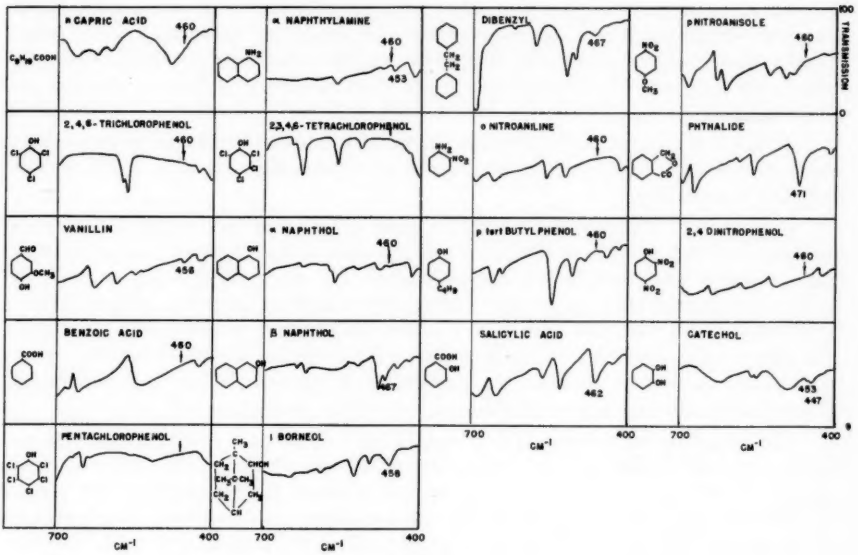


Figure 5

coupling of the odorous and pigment molecules, and on the closeness of the match between their natural frequencies of vibration.

The Low Frequency Vibrations of Some Mosquito Repellents

In principle, any agency which gives rise to an avoiding reaction is a repellent (1, 3), but for purposes of this discussion, attention must be focussed on the olfactory repellents. These are characterized by their distance action (which distinguishes them from gustatory or contact repellents), by the speed and directional nature of their effects (which distinguishes them from mere stimulants or irritants) and by a degree of chemical stability and inertness which renders it unlikely that they will operate through the common chemical sense. On the basis of present knowledge it is not usually possible to assign any particular substance unequivocally to one or other of the various categories, and some at least may act in more than one way. Generally speaking, however, substances which are liquids or solids with melting points below about 50°C are likely to be volatile enough to have a distance effect, and if they are at the same time neither markedly acid or alkaline and not noticeably irritating they are not likely to act on the common chemical sense.

On the basis of this reasoning, the twenty-five substances shown in Figure 4 were classed as being in all probability true olfactory repellents and their infrared absorptions in the range 700 to 400 cm^{-1} were then recorded. Thirteen of these substances have either found large scale application as mosquito repellents or have recently shown considerable promise in this respect. The remaining twelve are substances which were placed by Morton, Travis and Linduska (6) in the class showing the highest degree of repellency by their test methods.

Figure 5 shows the infrared absorption in the same region for eighteen additional repellents (6) whose mode of action is somewhat doubtful either

because of their lack of volatility (they all melt above 50°C) or their chemical reactivity (they include a large proportion of acids and phenols). It is noteworthy that many of these substances have marked flea repellent properties (5) which are far more likely to be gustatory than olfactory and so to depend on direct contact.

Figure 6 shows the infrared absorption of a control group of twenty-eight non-repellents (6) seventeen of which are liquid and the remainder solids at the ordinary temperature.

The infrared absorption was studied using a Perkin-Elmer Model 21 Infrared Spectrophotometer with potassium bromide optics, and a linear wave-number cam. Liquids were run as thin films between KBr plates, and solids as mulls in nujol, or, in a few cases, as pressed films with potassium bromide. The samples were commercial materials and were not usually purified before being examined. The range 700 to 400 cm^{-1} is only a part of the region which, from Figure 1, would be expected to include the "olfactory frequencies" but it is the range which was experimentally accessible with available equipment.

The members of the repellent group, Figure 4, show a marked tendency to absorb infrared radiation—and therefore to vibrate—with a frequency in the vicinity of 460 cm^{-1}. Thus 13 of the substances have distinct peaks in the range 449-467 cm^{-1} and five of the remainder show continuous absorption in all or part of this range. Of the remainder p-anisidine and caprylic acid may be acting on the common chemical sense, and are, in any event, with benzal acetone and phenylethyl alcohol in the group whose repellency is less securely established than that of the rest. Dimethyl phthalate, dimelone, and N,N diethyl benzamide are the most important exceptions.

In order that a molecular vibration may give rise to infrared absorption, it is necessary that the dipole moment of the molecule change during the course of the vibrational movements. Dimethyl phthalate has a plane of symmetry so that a stretching mode perpendicular to this plane would not be infrared active. It is thus conceivable that a vibrational mode of the right frequency does exist but is not represented in the infrared spectrum.

The case of dimelone is interesting in that this substance is a solid at the ordinary temperature but melts at 32-38°C. The infrared absorption of this substance was recorded both as a liquid and as a solid dispersed in nujol. As a general rule the positions of the absorption peaks of substances agree under these conditions within one or two wave numbers, but in dimelone the peaks which are at 515 and 476 cm^{-1} in the liquid are shifted to 504 and 489 cm^{-1} respectively in the solid. It is therefore apparent that in this substance the frequencies of the fundamental vibrational modes are unusually sensitive to the physical state of the molecules.

At the present time, an attempt is being made to study the infrared absorption of all these substances in the vapor state where the frequencies will be subject to a minimum of perturbation and where they will probably be most nearly in the condition in which they are perceived by the organism.

For the substances shown in Figure 5 whose mode of repellence is less likely to be olfactory, the infrared correlation is less strong, and only 7 or 8 out of 18 have peaks in the range 449-467^{-1}. These include, however, vanillin, borneol, and dibenzyl whose repellency it would be difficult to attribute to action on the common chemical sense.

In the control group of 28 substances shown in Figure 6 only ethyl salicylate, beta naphthylamine, methyl beta naphthyl ketone, and triphenyl methane have

B & Z LIBRARY

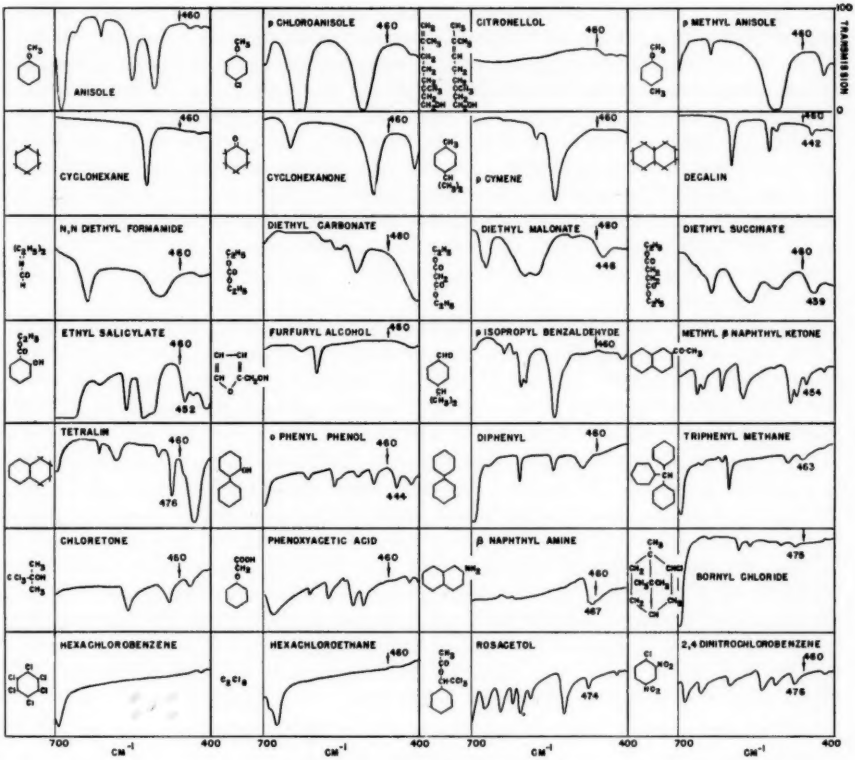


Figure 6

peaks between 449 and 467 cm^{-1}. Of these, ethyl salicylate may have escaped classification as a repellent because it was too volatile and triphenyl methane because it was not volatile enough.

Taking into account the many uncertainties in the screening methods used in assigning these substances to their various categories of repellency and non-repellency, the degree of correlation between repellency and a vibrational mode near 460 cm^{-1} is very striking and constitutes for the time being one of the principal pieces of experimental evidence directly supporting the vibrational hypothesis of odor causation.

The Mechanism of the Repellent Action

On the basis of the foregoing results, it might be concluded simply that a vibrational frequency at or near 460 cm^{-1} can get a signal through to the insect and produce a response directing the insect away from the source of the odor. But a factor which is at first sight embarrassing is the possession by water vapor of a well-defined infrared absorption maximum at 457 cm^{-1}. Thus it might be concluded that water ought to function as a repellent, whereas it is commonly regarded as an attractant to mosquitoes.

Closer consideration shows, however, that the matter may be reconciled, and new light thrown on the whole problem of repellent action.

Brown, Sarkaria and Thompson (12), showed that when female *Aëdes aegypti* were maintained in a large enclosure with a relative humidity (R.H.) of 36-50 percent, they were preferentially attracted to an air stream of substantially the same temperature but having a R.H. of 80-90 percent. When the R.H. of the room was 50-65 percent, the moist air was no less attractive, but when the ambient humidity was raised to 75-85 percent, the attractancy of the moist air stream was very significantly reduced. In another experiment, using blackened balls covered with wet or dry cloth, when the R.H. of the room was 30-40 percent the ball with the moist surface was approximately seven times as attractive as the one with a dry surface; but when the comparison was repeated in a room at a R.H. of 80 percent, the dry black ball was 2.5 times as attractive as the moist one.

Again, Roth and Willis (14) observed that when female *A. aegypti* were given a choice between 0 and 100 percent R.H. the results were erratic and the insects remained almost constantly in flight, apparently in an attempt to avoid both extremes. When the choice was between 75 percent R.H. and 100 percent R.H., the insects preferred the lower humidity.

Brown *et al* (12) quote an observation by De Long and coworkers that the human arm is only attractive to *A. aegypti* when the R.H. is 95 percent or less, and becomes unattractive at conditions of 100 percent saturation. In a later paper (15) Brown reports that when the attractiveness of different individuals to female *A. aegypti* was compared, it was found that dry-skinned persons were very significantly more attractive than those with moist skins, and that the greater the difference in moisture output between pairs of subjects, the greater was the differential attractiveness of the individual with the drier skin. The same preference was found when one hand of the subject was induced to perspire by vasodilation and compared with the other hand in its normal condition.

Thus it is evident that water vapor is not attractive to *A. aegypti* at all concentrations, and that at a sufficiently high concentration it becomes a repellent. This is by no means unusual, for Dethier (1) points out that substances which are repellent at low concentration continue to be repellent at high concentration, whereas substances which are attractant at low concentration invariably become repellent at high enough concentrations.

According to Brown (15) no less than six factors can be recognized as helping to guide female mosquitoes to their animal host, three of these being air-borne (water vapor, carbon dioxide, and convective heat) and three visual (movement, contour and reflectivity). The ability of certain repellent substances to overcome the effect of these factors has been recognized but not hitherto explained. The coincidence between the vibrational frequency common to most mosquito-repellent substances and one of the more distinctive infrared frequencies of water vapor may furnish a clue to the nature of the repellent action.

As has been pointed out above, the nature of the olfactory sensation may be attributed to the possession by the odorous substance of certain particular vibrational modes or frequencies, but the intensity of the sensation produced by any given molecular concentration of the odorous substance will depend upon the closeness of its coupling with the "trigger" molecules of pigment in the olfactory end organ. Thus, two substances with a common vibrational frequency, and hence with a similar "odor" might still have odors of vastly different strength or intensity if one were strongly adsorbed onto the surface of the end organ and the other only very weakly adsorbed. If members of the mosquito-repellent group of substances are adsorbed very strongly in comparison with molecules of

water, then it would be expected that a small concentration of the repellent substance should produce a response on the part of the insect similar to that produced by a very large concentration of water vapor molecules. In short, if the suggestion made here is correct, the repellent substances owe their repellent action to the fact that they are able to produce an illusion of high humidity and so evoke the avoiding reaction which high humidities are known to produce.

This suggestion has the merit that it connects the repellency of these substances with an already known behavioural pattern of the insect so that the locomotory effect of the repellent is presumably mediated by and through the central nervous system along a route which is already known to exist. It is also, perhaps, significant that Roth and Willis (14) have shown that the antennae of female *A. aegypti* carry the water vapor sense, that it is correlated with the distribution of thin-walled sensilla (trichoid and/or basiconica) on the antennae; and that the antennal segments in question are darkly pigmented.

An experimental test of this mechanism of repellent action could be carried out as follows. Sarkaria and Brown (13) have described an apparatus and technique whereby the response of female *A. aegypti* to streams of air containing small amounts of repellent vapors could be demonstrated. In their experiments, the mosquitoes were maintained in a large room at a R.H. of 40-50 percent. The extent to which they were drawn towards air inlets with and without added repellent vapors was then observed, and it was found that under the conditions of test the well-known repellents all evoked an avoiding reaction. If the mechanism of the repellent action which is suggested here is correct, it may be predicted that if the experiment were repeated with the mosquitoes in a room at or near zero relative humidity, then an attractive action should be observed at air inlet ports which introduced dry air containing a small amount of a repellent such as indalone. This would provide a very simple and direct experimental test of the theory.

Acknowledgments

Particular thanks are due to Dr. A. M. Crooker for the loan of equipment and for his continuing interest and helpful advice.

The donation of samples of repellent and other substances by the following individuals and firms is also gratefully acknowledged: Dr. Hubert Martin, Dr. D. G. Peterson, the Sherwin Williams Co. of Canada Ltd., Givaudan Canada, Ltd., the Van Ameringen Haebler Co., Firmenich, Inc., and A. Boake, Roberts and Co.

The Perkin-Elmer infrared Spectrophotometer was purchased with a consolidated grant from the National Research Council of Canada.

References

(1) Dethier, V. G. 1947. Chemical insect attractants and repellents. Blakiston, Philadelphia.
(2) Dethier, V. G. 1954. The physiology of olfaction in insects. *Ann. N.Y. Acad. Sci.*, 58, Art. 2, 139-157.
(3) Dethier, V. G. 1956. Repellents. in *Ann. Rev. of Entomology*, Vol. 1, 181-202. (Annual Reviews, Inc.).
(4) Hainer, R. M., A. G. Emslie and A. Jacobson. 1954. An information theory of olfaction. *Ann. N.Y. Acad. Sci.*, 58, Art. 2, 158-174.
(5) Linduska, J. P., J. H. Cochran and F. A. Morton. 1946. Flea repellents for use on clothing. *J. Econ. Entomol.* 39, 767-769.
(6) Morton, F. A., B. V. Travis and J. P. Linduska. Evaluation of mosquito repellents. U.S. Bureau of Entomology and Plant Quarantine, Sept. 1947, E-733.
(7) Wright, R. H. 1954. Odor and chemical constitution. *Nature*, 173, 831.
(8) Wright, R. H. 1954. Odor and molecular vibration. I. Quantum and thermodynamic considerations. *J. Appl. Chem.*, 4, 611-615.

(9) Wright, R. H. and R. S. E. Serenius. 1954. Odor and molecular vibration. II. Raman spectra of substances with the nitrobenzene odor. *J. Appl. Chem.*, 4, 615-621.
(10) Wright, R. H., C. Reid and H. G. V. Evans. 1956. Odor and molecular vibration. III. A new theory of olfactory stimulation. *Chem. and Ind.*, 1956, No. 37, 973-977, Sept. 22.
(11) Wright, R. H. 1956. The physical basis of insect repellency. *Nature*, 178, 638.
(12) Brown, A. W. A., D. S. Sarkaria and R. P. Thompson. 1951. Studies on the responses of female *Aëdes* mosquito. Part I. The search for attractant vapors. *Bull. Ent. Res.*, 42, 105-114.
(13) Sarkaria, D. S. and A. W. A. Brown. 1951. Studies on the responses of female *Aëdes* mosquito. Part II. The action of liquid repellent compounds. *Bull. Ent. Res.*, 42, 115-122.
(14) Roth, L. M. and E. R. Willis. 1952. Possible hygroreceprors in *Aëdes aegypti* (L.) and *Blatella germanica* (L.). *J. Morph.* 91, 1-14.
(15) Brown, A. W. A. 1956. Factors which attract *Aëdes* mosquitoes to humans. Tenth International Congress of Entomology.

Note on the Status of Some Genera in the Family Phytoseiidae (Acarina)

By D. A. CHANT[2]
Entomology Laboratory, Belleville, Ontario

Mites of the family Phytoseiidae, most of which are at least partially predacious, have received considerable attention from fruit entomologists since Parrott *et al.* (1906, pp. 302-303) stated that they feed extensively on phytophagous mites. This has resulted in much interest in the taxonomic status of Phytoseiidae and several papers on this subject have appeared in recent years.

Early workers were largely concerned with describing new species. In 1948 Garman revised the family and used certain setal characters of the dorsal and ventrianal shields of adult females as a basis for specific separation. In 1951 Nesbitt further revised the family, using Garman's system of chaetotactic nomenclature; he discussed in detail the synonomy and taxonomic history of these mites. Nesbitt included the genera *Amblyseius* Berlese, 1914, *Typhlodromus* Scheuten, 1857, and *Amblyseiopsis* Garman, 1948, in the family and it is with these and the genus *Amblyseiella* described by Muma (1955) that the present paper is concerned. At present, these genera are considered valid and the criteria for their separation are the relative lengths of certain setae on the dorsal shield and the relative widths of the genital and ventrianal shields of the adult female.

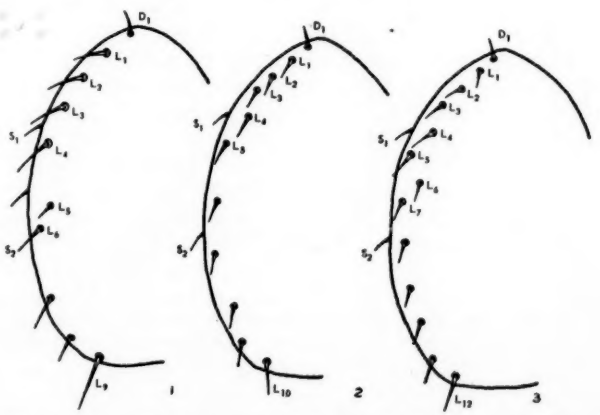
Evans(1952) stated that he did not consider that the characters used by Garman (1948) to erect the subgenus *Amblyseiopsis* within *Amblyseius* justified such a procedure; Garman based this subgenus on the fact that the ventrianal shields of females of this group are narrower than the genital shields, whereas in *Amblyseius*, as he conceived it, the ventrianal is wider than the genital shield. Muma (1955) considered *Amblyseiopsis* to be of generic stature and erected a new genus, *Amblyseiella*, based on the relative widths of the genital and ventrianal shields. Evans was justified in his objection to this criterion being of taxonomic significance as within these genera are found mites with shields of equal widths and also mites in which one or the other is wider; in other words, a series can be demonstrated. If the objection is accepted we have, then, two genera: *Typhlodromus* and *Amblyseius* (including *Amblyseiopsis* and *Ambly-*

[1]Contribution No. 3551, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
[2]Associate Entomologist.

seiella), distinguished by the relative lengths of certain setae on the dorsum. By Garman's system of setal nomenclature, in *Amblyseius* L4, L9, and M2 are noticeably longer than the remaining setae of the dorsal shield. In *Typhlodromus* this is not the case.

Recently, Bernhard (1955) revised the entire family *Phytoseiidae*, and radically departed from present concepts. Some of these changes apparently violate many established rules of nomenclature, but one is of merit in the opinion of the present author. This was to combine the genera *Amblyseius* and *Typhlodromus* as subgenera of *Typhlodromus sensu lato*. The morphological distinctions between the two genera are artificial and such a combination seems logical and acceptable. However, the present author considers that Bernhard's reasons for this combination, and the basis he has chosen for distinction between the new subgenera, are not always applicable and wishes to suggest other criteria for separation that may be more nearly fundamental. Evans (in preparation) has incorporated Bernhard's revision of the two genera in his key to the Phytoseiidae.

Because the pattern of setae both dorsally and ventrally in these two genera is identical, regardless of relative lengths, combination is certainly justified. In *Amblyseius* as described by Berlese (1914), L4, L9, and M2 are longer than other dorsal setae, whereas in *Typhlodromus* as defined by Nesbitt (1951) they are not. However, in *Typhlodromus* all dorsal setae may be of extreme length, as in *T. longipilus* Nesbitt and *T. occidentalis* Nesbitt, and apparently this character is not of generic value. For this reason Bernhard combined the genera, but he considered there was a genuine difference that divides mites of this type into two groups which might well be used at a subgeneric level.

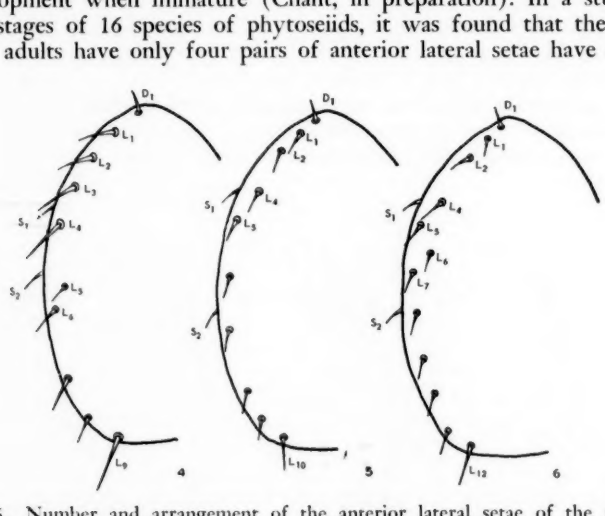


Figs. 1-3. The number and arrangement of the anterior lateral setae of three phytoseiids. 1, subgenus *Amblyseius* with four anterior laterals (L1-L4). 2, subgenus *Typhlodromus* with five anterior laterals (L1-L5). 3, subgenus *Typhlodromus* with an unbroken row of lateral setae from L1 to L12, and at least five anterior lateral setae.

Bernhard noticed from the few phytoseiid species present in Bavaria that two types were present: those with one lateral seta (L4) present on the dorsum between the sacral setae S1 and S2, and those with three setae (L4, L5, and L6) in that position. He considered *T.* (*Amblyseius*) as of the former (the type of Berlese's genus, *A. obtusus* Berl. (ex Koch), is of this sort) and *T.* (*Typhlodromus*) as of the latter (the type of Scheuten's genus, *T. tiliae* Oudemans (=*?T.*

pyri Scheuten), possesses three setae between S1 and S2). However, all species cannot be as easily classified as those with which Bernhard worked. In some, S2 is absent as in *T. longipilus* and *T. pomi* Parrot, whereas in others more than three setae appear between S1 and S2, as in *T. australicus* (Womersley). Therefore, simple division is not possible and one must look further for a sound basis. In all phytoseiids belonging to this group there are a certain number of lateral setae on the dorsum more or less grouped on the anterior edge, or "shoulder", of the dorsal shield. In many species, including *A. obtusus*, four pairs of these are present with a distinct gap between them and L5 and L6 (which are close together); in others, more pairs are present; and in some an unbroken row of setae extends along the entire lateral margin of the shield (Figs. 1-3).

Where only four pairs of anterior lateral setae are present, only one occurs between S1 and S2 (if present) and, when a greater number are present, more appear in this position. Hence separating the two subgenera on the basis of the number of anterior lateral setae present on the dorsal shield is less open to misinterpretation than Bernhard's original statement. To justify this separation more fully, it was found that the two groups (i.e., those with four pairs of anterior lateral setae and those with five pairs or more) exhibit different types of setal development when immature (Chant, in preparation). In a study of the immature stages of 16 species of phytoseiids, it was found that the species of which the adults have only four pairs of anterior lateral setae have a complete



Figs. 4-6. Number and arrangement of the anterior lateral setae of the protonymphs of three phytoseiids. 4, subgenus *Amblyseius* with four setae as in the adult. 5 and 6, subgenus *Typhlodromus* without L3, which is present in the adult.

complement of dorsal setae in the protonymph stage; that is, four pairs of anterior lateral setae are present throughout nymphal development. In those species of which the adults have five or more anterior lateral setae on the dorsal shield, one seta is missing in the protonymphs, and a complete complement of dorsal setae is not present until the deutonymphal stage is attained (Figs. 4-6).

A distinct gap is present between the second and third anterior lateral setae in the protonymphs of species that have five or more anterior laterals when adult, and it is concluded that L3 is missing.

It is doubtful whether this difference justifies separation at a generic level, but certainly subgeneric separation is valid. Therefore, within the genus *Typhlo-*

dromus as at present defined there are two subgenera: *Amblyseius* with four pairs of anterior lateral setae on the dorsum (and never more than a total of nine pairs of lateral setae), and *Typhlodromus* with more than four pairs of anterior lateral setae. Nesbitt (1951) reduced the name *Neoseiulus* Hughes to subgeneric status for use with those species that have 10 pairs of lateral setae on the dorsum, but did not designate other names for those with other numbers of lateral setae. The present author considers this distinction unjustified because species with 10 pairs of lateral setae are not necessarily closely related. The subgenus *Typhlodromus* can be divided for convenience into "species groups" on the basis of the total number of lateral setae present, 8, 9, 10, 11, or 12 pairs. However, the definition of the genus *Typhlodromus* should be modified to make distinction between it and allied genera easier. Nesbitt considered it sufficient to state that members of that genus have not more than 18 pairs of setae on the dorsal shield and at least three pairs of setae on the ventrianal shield of the adult female. However, he included in the genus *T. tiliarum* Oudemans (with 19 pairs of setae on the dorsum) and *T. soleiger* (Ribaga) (with 19 pairs of setae, including three median (M) setae, on the dorsum, and only two pairs on the ventrianal shield of the female). Womersley (1954) described a species with 20 pairs of setae on the dorsal shield, and "*Amblyseiella*" *setosus* Muma has but one pair on the ventrianal shield. The difficulty lies in distinguishing between allied genera that have upwards of 25 pairs of setae on the dorsum (such as *Garmania* Nesbitt and *Blattisocius* Keegan). However, these do not exhibit a setal pattern similar to that of *Typholodromus* in that more than one row of lateral setae are present on the dorsum. It would therefore be advisable to place no restriction on the number of lateral setae within the genus *Typhlodromus* provided that only one row is present and that not more than three median setae and six dorsal (D) setae are present.

For the present *T. heveae* Oudemans and *T. hevearum* Oudemans are placed in the subgenus *Amblyseius*, though the degree of serration of the lateral setae is somewhat greater than usual. However, Chant (1955) showed that this may be a result of seasonal dimorphism. Likewise, *T. transvaalensis* (Nesbitt) is placed in the subgenus *Typhlodromus*. All of these were included by Nesbitt (1951) in the genus *Kampimodromus* Nesbitt, but Chant (1955) showed this to be synonomous with *Typhlodromus*. With some of these species, and with others falling in the subgenus *Amblyseius*, the number of dorsal setae is reduced posteriorly, but anteriorly four pairs of anterior lateral setae are always detectable.

Bernhard included *Phytoseius* Ribaga as a third subgenus of *Typhlodromus* but the form of its lateral setae is very different: they are almost featherlike, are long, and sometimes are on protruberances. Also, of greater importance, setae S1 is on the dorsal shield instead of on the interscutal membrane in both adult forms, rather than only in the male as Evans (1952) has shown with other phytoseiids. The form and position of dorsal setae seem to be the most valid criteria available for generic separation in this group.

Summary

The genera *Amblyseius*, *Typhlodromus*, *Amblyseiopsis*, and *Amblyseiella* in the family Phytoseiidae are shown to be synonomous. However, the presence of two distinct types of setal pattern within the group justifies the division of *Typhlodromus* into two subgenera: *Typhlodromus* and *Amblyseius*.

Acknowledgments

The author wishes to thank Dr. Fritz Bernhard and Dr. Werner Hirschmann for the helpful discussions he had with them and other members of the staff of

the University of Erlangen on the systematics of the family Phytoseiidae, and Dr. A. Melis, Director of the Stazione di Entomologia Agraria, Florence, for permission to study the Berlese type specimens. Thanks are also due to Dr. G. Owen Evans of the British Museum (Natural History), London, for his advice on this paper.

References

Berlese, A. 1914. Acari nuovi. *Redia* 10: 113-150.
Bernhard, F. 1955. Ph.D. thesis. University of Erlangen, Germany.
Chant, D. A. 1955. Notes on the mites of the genus *Typhlodromus* Scheuten, 1857 (Acarina: Laelaptidae), with descriptions of the males of some species and the female of a new species. *Canadian Ent.* 87: 496-503.
Evans, G. Owen. 1952. On a new predatory mite of economic importance. *Bull. Ent. Res.* 43: 397-401.
Evans, G. Owen. 1954. The genus *Iphiseius* Berl. (Acarina: Laelaptidae). *Proc. Zool. Soc. London* 124: 517-526.
Garman, P. 1948. Mite species from apple trees in Connecticut. *Connecticut Agr. Expt. Sta. Bull.* 520.
Muma, M. H. 1955. Phytoseiidae (Acarina) associated with citrus in Florida. *Ann. Ent. Soc. America* 48: 262-272.
Nesbitt, H. H. J. 1951. A taxonomic study of the Phytoseiinae (Family Laelaptidae) predacious upon Tetranychidae of economic importance. *Zool. Verh.*, Leiden, 12.
Parrott, P. J., H. E. Hopkins, and W. J. Schoene. 1906. The Eriophyidae. Part I. The apple and pear mites. *New York State Agr. Expt. Sta. Bull.* (Geneva) 283.
Womersley, H. 1954. Species of the subfamily Phytoseiinae (Acarina: Laelaptidae) from Australia. *Australian J. Zool.* 2: 169-191.

(Received April 30, 1957)

Note on *Aedes melanimon* Dyar, a Mosquito New to Canada (Diptera: Culicidae)[1]

By LAWRENCE BURGESS[2]
Veterinary and Medical Entomology Unit
Ottawa, Ont.

Four males of *Aedes melanimon* Dyar were collected in mosquito traps during flight studies on the prairie near Brooks, Alberta, in 1956. One of the specimens was taken on July 14, and two on July 24; the collection date of the fourth specimen is unrecorded. The determinations were made by Dr. J. R. Vockeroth, Entomology Division, Ottawa, from preparations of the genitalia. This is the first time that this species has been recorded from Canada; it was previously known only from the western United States. It is possible that females of this species have been collected in Canada but have not been recognized because of the similarity to *A. dorsalis* (Meig.). Barr (1955) and Richards (1956) have reviewed the specific status of *Aedes melanimon* Dyar and compared the morphology of this mosquito with that of other closely related species.

References

Barr, A. R. 1955. The resurrection of *Aedes melanimon* Dyar. *Mosquito News* 15: 170-172.
Richards, C. S. 1956. *Aedes melanimon* Dyar and related species. *Canadian Ent.* 88: 261-269.

[1]Contribution No. 3635, Entomology Division, Science Service, Department of Agriculture, Ottawa, Canada.
[2]Assistant Entomologist.

(Received August 7, 1957)

THE RUNGE PRESS LIMITED, OTTAWA
Mailed: Friday, December 6, 1957)